WORKING paper

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EUROSYSTÈME

Capital Requirements in Light of Monetary Tightening[1]

Aurélien Espic[2], Lisa Kerdelhué[3], Julien Matheron[4]

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Abstract

This paper studies the role of capital requirements in a context of monetary tightening. We build a new Keynesian model featuring costly defaults for banks, households and firms, and estimate it on Euro Area data between 2002 and 2023. We first identify the sources of this unprecedented episode before studying its propagation along financial variables. We then build various counterfactuals to assess how capital requirements have affected the transmission of this shock. We find that although capital requirements reduced the post-Covid expansion, they preserved macroeconomic stability by reducing banks probability of default. More generally, we show that capital requirements do not need to be countercyclical to be efficient: in an inflationary context, they act as automatic stabilizers, by limiting the amplitude of expansionary as well as recessionary shocks.

Keywords: Monetary Tightening, Financial Stability, Macroprudential Policy.

JEL classification: E44, E52, G21, G28

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[2] Banque de France, Aix-Marseille University, Aix-Marseille School of Economics, aurelien.espic@banque-france.fr.
[3] Banque de France, lisa.kerdelhue@banque-france.fr.
[4] Banque de France, Paris School of Economics, julien.matheron@banque-france.fr.

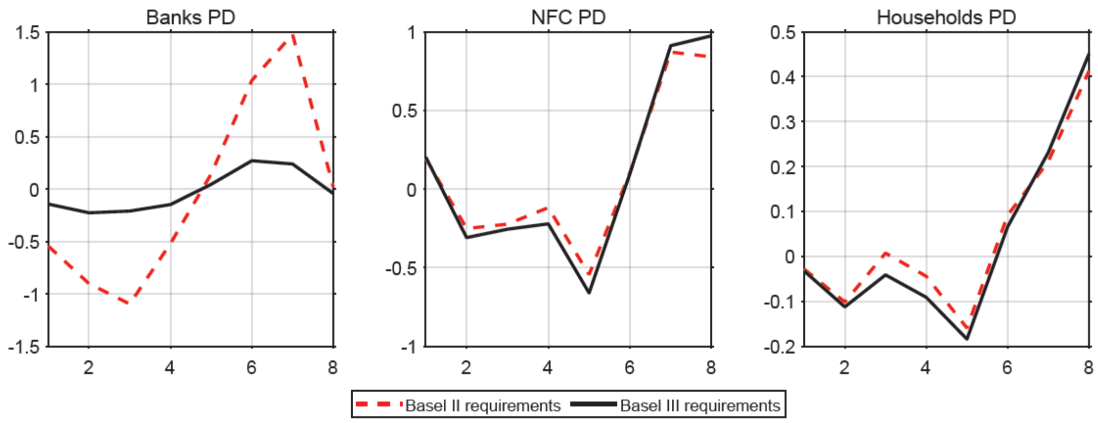
NON-TECHNICAL SUMMARY

Starting in the summer of 2021, the Euro Area experienced a significant surge in inflation, with the harmonized index of consumer prices index reaching a year-on-year growth rate of 10.6% in October 2022. This prompted the reaction of the European Central Bank, which dramatically rose its key interest rates, thereby increasing the 3-month Euribor from -0.5% in March 2022 to 3.88% in September 2023. The sudden rise in interest rates, as well as subdued growth prospects and heightened uncertainty, put financial stability concerns at the forefront of policy debates, given the strong empirical link between monetary policy tightening and financial crises. Is this time different? This paper argues that the response largely hinges on the level of banks' capital requirements.

Indeed, the prudential environment faced by banks is very different compared to past monetary tightening episodes. In particular, following the 2008 Great Financial Crisis, European countries adopted a number of prudential tools to increase banks' capital requirements, notably in order to enhance their loss absorption capacity. Although some of these tools have initially been considered as countercyclical instruments, competent authorities have reconsidered this approach during the historical monetary tightening of 2021-2023. Despite a significant credit growth slowdown, these capital reserves were not released, while some jurisdictions went as far as tightening their stance. Overall, these buffers have rather been used to strengthen banks' resilience, rather than to tame the financial cycle.

To address the contribution of capital requirements to the transmission of this rise in interest rates, we build a structural macroeconomic model with a rich set of nominal and financial frictions. We then estimate it on Euro Area data up to 2023-Q2, in order to identify the shocks that drove interest rates up. As the model features an explicit banking sector, we can then design counterfactual scenarios regarding the level and design of capital requirements. We first find that the shocks driving the post-Covid inflation growth were related to consumption catch-up, as well as the decrease in the relative price of tangible assets, which fostered investment. Against this backdrop, micro-prudential capital requirements proved to be efficient automatic stabilizers: while they slightly tamed GDP growth during the 2022 expansion, they decreased banks' probability of default at the beginning of 2023, thereby protecting credit and activity in times of slowdown.

Figure 1. Probabilities of default and capital requirements in the euro area (2021Q3- 2023Q2)



Note: The y-axis represents deviations from steady state in percentage point. The x-axis represents quarters, the first one being Q3 2021. Minimal Basel III requirements (without countercyclical capital buffer) were set at 10.5% of risk-weighted assets, against 8% for Basel II requirements.

These results rely on the combination of shocks that describes this episode: while the exogenous shock on the relative price of investment contributed negatively to the efficiency of capital requirements, banks' and firms' risks shocks contributed positively. We also find that capital requirements had heterogeneous effect between savers and borrowers: while the former increase consumption and reduce housing stocks, the latter have an opposite reaction. Finally, we find that macro-prudential measures, especially a household-specific capital buffer, provided additional layers of protection.

Overall, these findings highlight the usefulness of capital requirements to ensure the resilience of the economy in the face of business and financial cycles, so that monetary policy may be less constrained in its action. Indeed, capital requirements may eliminate the possibility of a hard landing, especially if banks bear interest risks. In addition, capital-based macroprudential policies enable to enter a monetary policy tightening cycle with sufficient capital buffers, and thus significantly contribute to macroeconomic stability, by maintaining bank profitability and credit supply. However, capital buffers per se are not sufficient to guarantee alone macrofinancial stability, as they sustain credit supply provided they are not set too high. Complementary borrower-based measures can then be a useful complement to ensure appropriate leverage, although they are beyond the scope of this paper.

Les exigences en capital à l'aune du resserrement monétaire

RÉSUMÉ

Cet article étudie le rôle des exigences en capital dans un contexte de resserrement monétaire. Nous construisons un modèle néo-keynésien dans lequel banques, ménages et entreprises peuvent faire défaut, et que nous estimons à partir de données de la zone euro, entre 2002 et 2023. Nous identifions dans un premier temps la source de cet épisode sans précédent avant d'étudier sa propagation aux des variables financières. Nous élaborons ensuite divers contrefactuels pour évaluer le rôle des exigences en capital dans la transmission de ce choc. Nous constatons que bien que les exigences en capital aient réduit l'expansion post-Covid, elles ont préservé la stabilité macroéconomique en réduisant la probabilité de défaut des banques. Plus généralement, nous montrons que les exigences en capital n'ont pas besoin d'être contracycliques pour être efficaces : dans un contexte inflationniste, elles agissent comme des stabilisateurs automatiques, en limitant l'amplitude des chocs expansionnistes ainsi que des chocs récessionnistes.

Mots-clés : resserrement monétaire, stabilité financière, politique macroprudentielle.

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1 Introduction

Starting in the summer of 2021, the Euro Area experienced a significant surge in inflation, with the harmonized index of consumer prices index reaching a year-on-year growth rate of 10.6% in October 2022[1]. This prompted the reaction of the European Central Bank, which dramatically rose its key interest rates, thereby increasing the 3-month Euribor from -0.5% in March 2022 to 3.88% in September 2023[2]. The sudden rise in interest rates, as well as subdued growth prospects and heightened uncertainty, put financial stability concerns at the forefront of policy debates, given the strong empirical link between monetary policy tightening and financial crises (Schularick and Taylor, 2012). Is this time different? This paper argues that the response largely hinges on the level of banks' capital requirements.

Indeed, the prudential environment faced by banks is very different compared to past monetary tightening episodes. In particular, following the 2008 Great Financial Crisis, European countries adopted a number of prudential tools to increase banks' capital reserves, notably in order to enhance their loss absorption capacity. The first measure was a reinforcement of microprudential tools, increasing structural buffers form 8% of risk weighted assets to 10.5%. The second one was the introduction of macroprudential tools, and in particular time varying and sector specific capital requirements[3]. This set of measures is defined at the European level, but their specific design and activation are enacted at the national level[4]. Although they have initially been considered as countercyclical instruments, in line with early contributions on the subject (Mendoza, 2010; Bianchi, 2011), competent authorities have reconsidered this approach during the historical monetary tightening of 2021-2023. Despite a significant credit growth slowdown, these capital reserves were not released, while some jurisdictions went as far as tightening their stance. Overall, these buffers have rather been used to strengthen banks' resilience, rather than to tame the financial cycle (Hempell et al., mimeo).

This paper takes stock on this prudential framework in a context of monetary tightening, as there are reasons to think this episode could have had more serious financial stability consequence. Indeed, changes in prices and in interest rates affect negatively banks' net worth and ultimately the supply of loans to firms and households via the bank balance sheet channel (Bernanke and Gertler, 1995; Jiménez et al., 2012). In addition, the rapid increase in interest rates could have led to the materialization of interest rate and credit risks if lenders had imperfectly hedged fixed income positions (Jiang et al., 2023) or if borrowers could not absorb the increase in financing costs

[1]Source: Eurostat.

[2]Source: Refinitiv.

[3]A third measure was the introduction of capital requirements targeting systemic institutions. This additional layer is beyond of the scope of this paper, as it requires a thorough modelling of heterogeneous banks.

[4]See ESRB website for more details.

(Jiménez et al., 2022).

To address the contribution of capital requirements to the transmission of this rise in interest rates, we build a structural macroeconomic model with a rich set of nominal and financial frictions. We then estimate it on Euro Area data up to 2023-Q2, in order to identify the shocks that drove interest rates up. As the model features an explicit banking sector, we can then design counterfactual scenarios regarding the level and design of capital requirements. We first find that the shoks driving the post-Covid inflation growth were related to consumption catch-up, as well as the decrease in the relative price of tangible assets, which fostered investment. Against this backdrop, micro-prudential capital requirements proved to be efficient automatic stabilizers: while they slightly tamed GDP growth during the 2022 expansion, they decreased banks' probability of default at the beginning of 2023, thereby protecting credit and activity in times of slowdown. These results rely on the combination of shocks that describes this episode: while the exogenous shock on the relative price of investment contributed negatively to the efficiency of capital requirements, banks' and firms' risks shocks contributed positively. We also find that capital requirements had heterogeneous effect between savers and borrowers: while the former increase consumption and reduce housing stocks, the latter have an opposite reaction. Finally, we find that macro-prudential measures, especially a household-specific capital buffer, provided additional layers of protection.

Overall, these findings highlight the usefulness of capital requirements to ensure the resilience of the economy in the face of business and financial cycles, so that monetary policy may be less constrained in its action. Indeed, capital requirements may eliminate the possibility of a hard landing, especially if banks bear interest risks. In addition, capital-based macroprudential policies enable to enter a monetary policy tightening cycle with sufficient capital buffers, and thus significantly contribute to macroeconomic stability, by maintaining bank profitability and credit supply. However, capital buffers *per se* are not sufficient to guarantee alone macrofinancial stability, as they sustain credit supply provided they are not set too high. Complementary borrower-based measures can then be a useful complement to ensure appropriate leverage, although they are beyond the scope of this paper.

Literature review. We contribute to a growing literature studying the relationship between inflation, monetary policy tightening and financial stress. Jiménez et al. (2022) and Boissay et al. (2021) show that an abrupt rise in interest rates following a period of loose monetary policy is likely to lead to financial stress. Boissay et al. (2023b) stress that the sources of inflationary shocks matter: supply-driven inflation tends to increase financial stress, but not demand-driven inflation. We contribute to this literature by estimating a structural macroeconomic model with financial frictions that enable to decompose the origins of the 2022-2023 monetary policy tightening. We find that although this precise inflationary episode is mainly supply-driven, it did not lead to sizeable financial stress partly thanks to prudential regulations implemented since the last monetary tightening episodes.

We thus relate to a second strand of literature studying the interplay between monetary and macroprudential policies. Much of the literature has focused on countercyclical capital requirements in a low interest rate environment (Rubio and Carrasco-Gallego, 2016; Rubio and Yao, 2020). We contribute to this literature by focusing on a high interest environment, which notably pushed policy makers to reconsider the countercyclical adjustment of capital requirements. We thus rather study the dynamic properties of a given capital requirement level and the resulting resilience in the face of exogenous inflationary shocks. From a theoretical point of view, Revelo and Levieuge (2022) show that monetary and macroprudential policies are in conflict in the case of supply-side and bank capital shocks. As our model stresses the effect banks' resilience may have on the economy while they focus on the countercyclical smoothing of the cycle, we find on the contrary that in these cases monetary and prudential policies can be complementary. In line with Boissay et al. (2023a), we find that tighter capital requirements give more room for monetary policy to fight inflation.

We finally contribute to the normative analysis of capital requirements in structural general equilibrium models. While these models take a far more simplified approach to banks' balance sheets than stress-test models, they allow to underline the second round effects financial shocks may have on macroeconomic stability and conduct a normative analysis of policy tools (Jondeau and Sahuc, 2022). Clerc et al. (2015), Mendicino et al. (2018) and de Bandt et al. (2022) analyse the impact of capital requirements in an economy in which banks, firms and households can default. Poutineau and Vermandel (2017), Mendicino et al. (2020), de Bandt et al. (2022) and Gasparini et al. (2023) use similar models in which only firms and banks can default, but augment it with nominal debt, price rigidities and monetary policy. Bratsiotis and Pathirage (2023) use such a model to assess the welfare and distributional effects of capital requirements. We complement the literature by introducing jointly price rigidities and default for banks, firms and households, enabling to further assess the financial channels of transmission of monetary policy, as well as its distributional impact. Moreover, we estimate such a model until 2023, enabling to focus on the role of capital requirements in the transmission of supply-side shocks to macroeconomic and financial variables.

The rest of the paper is structured as follows. Section 2 presents the model. Section 3 presents the estimation procedure. Section 4 presents the shocks identified by the model with a particular emphasis on the 2021-2023 period, as well as their effects on macroeconomic and financial variables. Section 5 quantifies the role of capital requirements in the transmission of these shocks. Section 6 concludes.

2 Model

This section presents an overview of the model, and the optimization problem of each type of agent. The full set of equilibrium conditions (optimality and market clearing) is reported in Appendix B.

The economy is inhabited by two types of infinitely-lived households (patient p and impatient i) differing by their discount factor ($\beta^i < \beta^p$). There is perfect risk-sharing between members of a household. Both types of households consume, supply labour and accumulate housing. On the one hand, patient households accumulate productive capital and save through bank deposits. In addition, they own all firms in the economy and pay a lump-sum tax to finance the partial deposit insurance provided by the government. On the other hand, impatient households borrow from banks and their members are subject to idiosyncratic housing quality shocks that can result in default, leading banks to impose a borrowing constraint.

There is a continuum of imperfectly substitutable intermediate goods, each produced by a monopolistic firm. The intermediate goods firms produce by combining rented physical capital and labour, and are subject to a Calvo price rigidity, resulting in price stickiness. Perfectly competitive firms then produce a homogeneous final good by combining intermediate goods. This final good is either consumed, or used by capital and housing producers who are subject to a dynamic adjustment cost. Capital is owned by both capital management firms and non-financial corporates (NFC). NFCs are owned by entrepreneurs, who are members of the patient household, and use bank loans. They are subject to idiosyncratic capital quality shocks that can result in default, leading banks to impose a borrowing constraint.

There are two types of banks. Both collect deposits from patient household, but some extend loans to impatient households, while the other type extend loans to NFCs. Each individual bank is subject to a portfolio management cost that can result in default. However, savers are myopic to the individual risk profile of the bank and do not impose a participation constraint. Therefore, banks have an incentive to over-leverage, letting some room for policy intervention, such as a capital requirement limiting loans to a fraction of equity. These banks are owned by bankers, who are members of the patient household and allocate resources such that expected returns are equal between each type of bank. Note that banks' balance sheet impacts the economy through two channels: the *net worth channel* as banks' profitability impacts the income flow accruing to patient households, and the *credit supply channel* as banks' profitability influences the tightness of the credit constrained faced by borrowing agents.

Finally, there are three public authorities: *(i)* a government levies lump-sum taxes to finance the deposit insurance agency and a stochastic flow of expenditures, *(ii)* a deposit insurance agency insures a fraction of deposits, and *(ii)* a monetary authority sets the short term nominal interest rate according to a Taylor rule.

This economy is hit by 11 structural shocks: a total factor productivity shock, a labour productivity shock, a price mark-up shock, a monetary policy shock, a time preference shock, a government spending shock, two investment shocks on housing and productive capital, and three risks shocks on housing, productive capital and banks' portfolio.

2.1 Households

Patient households. The economy is inhabited with a mass $m^p \in (0,1)$ of infinitely-lived patient households, each with a mass m^e of entrepreneurs, a mass m^b of bankers, and a mass $m^w = m^p - m^e - m^b$ of workers. In each period there is a probability $1-\theta^e$ that an entrepreneur is drawn to become a worker and a probability $1-\theta^b$ that a banker is drawn to become a worker. A commensurate mass of workers is drawn to replace exiting entrepreneurs and bankers, so that the relative mass of each type of household member is constant. The household collects earnings from each type of agent and ensures perfect risk sharing among its members.

The representative patient households has utility given by

$$\mathbb{E}_t\left[\sum_{s=0}^{\infty}(\beta^p)^s \mathrm{e}^{\zeta_{c,t+s}}\left(\log(c^p_{t+s}-\psi\bar{c}^p_{t+s-1})+\upsilon^p\log(h^p_{t+s})-\frac{\varphi^p}{1+\eta}\Theta^p_{t+s}(\ell^p_{t+s})^{1+\eta}\right)\right],$$

where c^p_t denotes the consumption of non-durable goods at t, $\bar{c}^p_t$ is the aggregate counterpart of c^p_t, h^p_t is the total stock of housing held by the household members, and ℓ^p_t denotes labour supply at t. The parameter $\varphi > 0$ s a scale factor, and $\eta > 0$ is the inverse of the Frisch elasticity. $\zeta_{c,t}$ is an exogenous taste shifter, obeying an $AR(1)$ process. Finally, we introduce an endogenous taste shifter Θ^p_t, taken as given by households of type p and obeying

$$\Theta^p_t = \frac{J^p_t}{\bar{c}^p_t - \psi\bar{c}^p_{t-1}}, \tag{2.1}$$

where

$$J^p_t = (J^p_{t-1})^{1-\zeta_J}[(\bar{c}^p_t - \psi\bar{c}^p_{t-1})]^{\zeta_J}. \tag{2.2}$$

The specification of the endogenous taste shifter follows Galí (2011) and Galí et al. (2011). Compared to Jaimovich-Rebelo preferences (Jaimovich and Rebelo, 2009), it introduces a distinction between the short-run wealth effect on labour supply and its long-run counterpart, through the parameter ζ_J.

The household maximizes the above objective subject to the sequence of budget constraints:

$$P_t c_t^p + D_t^p + Q_t^H h_t^p + (Q_t^K + P_t s_t^K) k_t^p + T_t^p \leq W_t \ell_t^p + \tilde{R}_t D_{t-1}^p + Q_t^H (1-\delta^H) h_{t-1}^p + (P_t r_t^K + (1-\delta^K) Q_t^K) k_{t-1}^P + \frac{1}{m^p} P_t \text{Div}_t \quad (2.3)$$

where P_t is the price of the non-durable good, W_t the nominal wage rate. T_t^p is a lump-sum tax, s_t^K is a per-unit real management cost taken as given by the household and paid to capital management firms, and Div_t is the sum of real net profits received by the patient households from capital good producers, monopolistic firms, entrepreneurs, financial intermediaries, and capital management firms.

D_t denotes the quantity of (nominal) deposits at t, paying the gross nominal interest rate $\tilde{R}_t$ at t. This return comes in two parts. A fraction $\kappa \in [0,1]$ is interpreted as insured deposits and pays the nominal interest rate R_{t-1} agreed upon in the deposit contract. The remaining fraction is interpreted as uninsured debt, paying back (i) R_{t-1} if there is no default and (ii) the net recovery value of bank assets otherwise. Banks' individual risk profile is unobservable to savers, so that their valuation of bank debt is based on the anticipated credit risk of an average unit of bank debt. It follows that

$$\tilde{R}_t = R_{t-1} - (1-\kappa)\Omega_t, \quad (2.4)$$

where Ω_t is the average default loss per unit of bank debt.

Impatient households. There is a mass $m^i = 1 - m^p$ of infinitely-lived, identical, impatient households. The representative impatient households has utility given by

$$\mathbb{E}_t \left[\sum_{s=0}^{\infty} (\beta^i)^s \mathrm{e}^{\zeta_{c,t+s}} \left(\log(c_{t+s}^i - \psi \bar{c}_{t+s-1}^i) + \upsilon^i \log(h_{t+s}^i) - \frac{\varphi^i}{1+\eta} \Theta_{t+s}^i (\ell_{t+s}^i)^{1+\eta} \right) \right],$$

where notations are similar to those used when expounding the patient households' problem. At t, the representative impatient household borrows the nominal amount B_t^i from banks, which is distributed across household members. In turn, each household member purchases h_t^i units of housing goods at nominal price Q_t^H. At the beginning of period $t+1$, the housing good is subject to an idiosyncratic shock ω_{t+1}^i drawn from a log-normal law with parameters $-\frac{1}{2}\mathrm{e}^{\zeta_{i,t}} \bar{\sigma}_i^2$ and $\mathrm{e}^{\zeta_{i,t}} \bar{\sigma}_i$, where $\zeta_{i,t} \sim AR(1)$. These shocks are *i.i.d.* across time and household members and are log-normally distributed. At $t+1$, the household member resells the undepreciated housing goods, earning the nominal amount $(1-\delta^H) Q_{t+1}^H h_t^i$ and pays the non-contingent gross nominal interest rate R_t^i on debt. The household member has the option of defaulting on debt. The impatient household thus seeks to maximize welfare subject to the resource constraint

$$P_t c_t^i + Q_t^H h_t^i \leq P_t w_t \ell_t^i + B_t^i + \int_0^\infty \max\{\omega^i (1-\delta^H) Q_{t+1}^H h_t^i - R_t^i B_t^i; 0\} f_{t+1}^i(\omega^i) d\omega^i.$$

and bank's participation constraint.

2.2 Production

Final good production. The final good is produced by perfectly competitive firms by combining a continuum of intermediate goods according to the constant-returns-to-scale CES production technology

$$y_t = \left(\int_0^1 y_t(f)^{\frac{1}{\mu_t}} df \right)^{\mu_t} \tag{2.5}$$

where $\mu_t = \mu e^{\zeta_{\mu,t}}$ is the mark-up of intermediary good producers with $\zeta_{\mu,t} \sim ARMA(1,1)$. Let P_t denote the nominal price of the final good and let $P_t(f)$ denote the nominal price of good f. Firms are price takers and seek to maximize nominal profits

$$P_t y_t - \int_0^1 P_t(f) y_t(f) df$$

Intermediary goods production. Intermediate good f is produced by monopolist f by combining labor and capital according to

$$y_t(f) = e^{\zeta_{a,t}} (k_t(f))^\alpha (e^{\zeta_{z,t}} \ell_t(f))^{1-\alpha}, \tag{2.6}$$

where $\alpha \in (0,1)$ is the elasticity of gross production with respect to capital, $\zeta_{a,t}$ a stochastic total factor productivity, and $\zeta_{z,t}$ a stochastic labour productivity. Both these variables follow and $AR(1)$ process. The rental rate of capital is r_t^K and the wage rate is w_t are taken as given by firm f. In a first step, firm f seeks to minimize production costs, given a production level $y_t(f)$:

$$\begin{aligned} &\min_{k_t(f),\ell_t(f)} \{r_t^K k_t(f) + w_t \ell_t(f)\} \\ &\text{s.t.} \quad e^{\zeta_{a,t}} (k_t(f))^\alpha (e^{\zeta_{z,t}} \ell_t(f))^{1-\alpha} = y_t(f), \\ &\qquad k_t(f) \geq 0, \;\; \ell_t(f) \geq 0, \end{aligned}$$

In a second step, firm f selects $P_t(f)$ so as to maximize the value to its shareholders (the patient households), taking the demand function of the final good producers into account. At t, firms thus value payoffs at $t+s$ via $(\beta^p)^s \lambda_{t+s}^p$, where λ_{t+s}^p is the marginal utility of consumption at $t+s$ for a patient household. Firm f faces nominal rigidities à la Calvo. In each period, firm f can reset its nominal price with probability $1-\xi$, $\xi \in (0,1)$. If not drawn to reset its price at t, firm f simply rescales $P_t(f)$ according to the mechanical rule $P_t(f) = (\Pi_*)^{1-\iota}(\Pi_{t-1})^{\iota}P_{t-1}(f)$, with $\iota \in (0,1)$, where $\Pi_t \equiv P_t/P_{t-1}$ and Π_* is the steady-state value of Π_t. Firm f thus selects $P_t^{\star}(f)$ so as to maximize

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta^p \xi)^s \frac{\lambda_{t+s}^p}{\lambda_t^p} y_{t+s} \left[\left(\frac{\Delta_{t,t+s} P_t^{\star}(f)}{P_{t+s}} \right)^{\frac{1}{1-\mu_t}} - mc_{t+s} \left(\frac{\Delta_{t,t+s} P_t^{\star}(f)}{P_{t+s}} \right)^{\frac{\mu_t}{1-\mu_t}} \right]$$

where

$$\Delta_{t,t+s} = \prod_{j=t}^{t+s-1} (\Pi_*)^{1-\iota}(\Pi_j)^{\iota},$$

And where mc_t is the real marginal cost solution to the cost minimization problem.

Housing good and capital good production. Capital and housing goods producers face a similar problem. Let $J \in \{K, H\}$ denote the type of durable good produced, H standing for housing and K for capital. These firms produce i_t^J new units sold at nominal price Q_t^J and are owned by the patient households. The firms technology is characterized by adjustment costs. In order to produce i_t^J units of new durable goods, the firm requires to spend

$$\left(1 + S_J\left(\frac{i_t^J}{i_{t-1}^J}\right)\right) i_t^J \mathrm{e}^{\zeta_{i_J,t}}$$

units of final good, where

$$S_J(X) = \frac{\psi_J}{2}(X-1)^2, \ \psi_J > 0, \zeta_{i_J,t} \sim AR(1).$$

Letting $q_t^J \equiv Q_t^J/P_t$, the typical capital producers seeks to maximize the value to their shareholders

$$\mathbb{E}_t \left\{ \sum_{t=0}^{\infty} (\beta^p)^t \lambda_t^p \left[q_t^J i_t^J - \left(1 + S_J\left(\frac{i_t^J}{i_{t-1}^J}\right)\right) i_t^J \mathrm{e}^{\zeta_{i_J,t}} \right] \right\}.$$

Capital management firms. Households can acquire units of physical capital subject to a management fee. The capital management cost s_t associated with households direct holdings of capital k_t^p is a fee levied by a measure-one continuum of firms operating with decreasing returns to scale. These firms have a convex cost function $z(m^p k_t^p)$ where $z(0) = 0$, $z'(\cdot) > 0$ and $z''(\cdot) > 0$. Capital management firms seek to maximize profits:

$$\mathrm{Div}_t^c = s_t^K m^p k_t^p - z(m^p k_t^p).$$

We assume a quadratic cost function

$$z(x) = \frac{\xi_s}{2}(x)^2 \tag{2.7}$$

with $\xi_s > 0$.

Entrepreneurs. At the beginning of period t, entrepreneur j has net worth $N_t^e(j)$. The period $t+1$ gross nominal return on investment projects is Z_{t+1}^e. The individual entrepreneur seeks to solve the program

$$\begin{aligned}
V_t^e = & \max_{\widetilde{\text{Div}}_t^e, E_t^e} \left\{ \widetilde{\text{Div}}_t^e + \mathbb{E}_t \left[\beta^p \frac{\Lambda_{t+1}^p}{\Lambda_t^p} [(1-\theta^e) N_{t+1}^e + \theta^e V_{t+1}^e] \right] \right\} \\
\text{s.t.} \quad & \widetilde{\text{Div}}_t^e + E_t^e \leq N_t^e, \\
& N_{t+1}^e = Z_{t+1}^e E_t^e, \\
& \widetilde{\text{Div}}_t^e \geq 0
\end{aligned}$$

Where Λ_t^p is the Lagrange multiplier associated to patient households' budget constraint.

Non-financial corporates. Investment project j receives equity $E_t^e(j)$ from entrepreneurs, together with debt $B_t^e(j)$ from banks. These funds are used to acquire $k_t^e(j)$ units of capital at price Q_t^K. The balance sheet of investment project j is thus

$$E_t^e(j) + B_t^e(j) = Q_t^K k_t^e(j).$$

The capital is then subject to a quality shock ω_{t+1}^e at $t+1$, where ω_{t+1}^e is drawn from a log-normal law with parameters $-\frac{1}{2}\mathrm{e}^{\zeta_{e,t}}\bar{\sigma}_e^2$ and $\mathrm{e}^{\zeta_{e,t}}\bar{\sigma}_e$, where $\zeta_{e,t} \sim AR(1)$. After the capital quality shock is revealed, the capital stock is rented to intermediate firms, earning the per unit nominal rental rate $P_{t+1} r_{t+1}^K$. The capital stock depreciates at rate δ^K and the remaining capital stock is sold back to capital producers at price Q_{t+1}^K. At the end of period $t+1$, the entrepreneurial firm pays the gross interest on debt R_t^e. The entrepreneurial firm thus maximizes the expected and appropriately discounted net profits

$$\mathbb{E}_t \left[\beta^p \frac{\Lambda_{t+1}^p}{\Lambda_t^p} (1 - \theta^e + \theta^e v_{t+1}^e) \max\left\{ \omega_{t+1}^e R_{t+1}^K Q_t^K k_t^e(j) - R_t^e B_t^e(j); 0 \right\} \right] - v_t^e E_t^e(j)$$

subject to banks' participation constraint, denoting

$$R_{t+1}^K = \frac{P_{t+1} r_{t+1}^K + (1-\delta) Q_{t+1}^K}{Q_t^K}.$$

And where ν_t^e is the Lagrange multiplier associated to entrepreneurs' balance sheet constraint.

2.3 Bankers and banks

Bankers. An individual banker starts period t with net worth N_t^b, which is invested as equity (i) in a continuum of investment projects E_t^F and (ii) a continuum of housing projects E_t^M. The period $t+1$ aggregate gross nominal return on these projects is Z_{t+1}^b. The individual banker seeks to solve the program

$$V_t^b = \max_{\widetilde{\text{Div}}_t^b, E_t^M, E_t^F} \left\{ \widetilde{\text{Div}}_t^b + \mathbb{E}_t \left[\beta^p \frac{\Lambda_{t+1}^p}{\Lambda_t^p} [(1-\theta^b) N_{t+1}^b + \theta^b V_{t+1}^b] \right] \right\}$$

$$\text{s.t.} \quad \widetilde{\text{Div}}_t^b + E_t^M + E_t^F \leq N_t^b,$$

$$N_{t+1}^b = Z_{t+1}^M E_t^M + Z_{t+1}^F E_t^F,$$

$$\widetilde{\text{Div}}_t^b \geq 0$$

Where Λ_t^p is the Lagrange multiplier associated to patient households' budget constraint.

Banks. At t, a bank of type $j \in \{M, F\}$ takes equity E_t^j from bankers and borrows D_t^j at gross rate R_t from households to extend loans B_t^j. Hence the balance sheet constraint

$$E_t^j + D_t^j = B_t^j.$$

The time $t+1$ return on a well diversified portfolio of loans is denoted R_{t+1}^j. The portfolio of loans is subject to a performance shock ω_{t+1}^j at $t+1$, where ω_{t+1}^j is drawn from a log-normal law with parameters $-\frac{1}{2} e^{\zeta_{B,t}} \bar{\sigma}_j^2$ and $e^{\zeta_{B,t}} \bar{\sigma}_j$[5], with $\zeta_{B,t}$ being common to both bank types and following an $AR(1)$ process. At the end of period $t+1$, the bank pays the gross interest on deposits. A bank of type j seeks to maximize

$$\mathbb{E}_t \left[\beta^p \frac{\Lambda_{t+1}^p}{\Lambda_t^p} (1 - \theta^b + \theta^b \nu_{t+1}^b) \max \left\{ \omega_{t+1}^j R_{t+1}^j B_t^j - R_t D_t^j ; 0 \right\} \right] - \nu_t^b E_t^j$$

Where ν_t^b is the Lagrange multiplier associated to bankers' balance sheet constraint.

Because of their limited liability, the pay-off accruing to shareholders of the bank cannot be negative. In case $\omega_{t+1}^j R_{t+1}^j B_t^j < R_t D_t$, the bank defaults. In this case, its equity is written down to zero and deposits are taken over by the Deposit Insurance Agency (DIA) which pays out an

[5] This parametric restriction implies $\mathbb{E}_t \omega_{t+1}^j = 1$.

exogenous fraction κ of deposits. The DIA partly recoups this by taking over the failed bank's loan portfolio minus resolution costs. Resolution costs are assumed to be a fraction μ^j of recovered funds.

Finally, the bank faces a regulatory capital constraint

$$E_t^j \geq \phi_t \gamma_t^j B_t^j \tag{2.8}$$

which states that the capital to asset ratio has to be greater than a (possibly) time-varying level set exogenously by the prudential authority. This level is decomposed into two components: a risk-weighted broad-based capital requirements ϕ_t, which is common to all banks, and risk weights γ_t^j, which are specific to the type of bank. We assume that these weights are set exogenously by the prudential authority, as in the the Basel standard approach to risk[6]. In equilibrium, this constraint holds with equality.

An important quantity in the model is the ex-post gross return on banks portfolio Z_t^j, as it directly affects the net worth of bankers and hence of savers, and indirectly through credit supply to NFCs and borrowing households. For simplicity we focus on the ex-post gross return of firm banks with constant capital requirements, using the fact that capital requirements are binding:

$$Z_t = \frac{1}{\phi} R_t^F \Upsilon(\bar{\omega}_t)$$

Where $\bar{\omega}_t$ is the value of bank's portfolio shock below which the bank defaults:

$$\bar{\omega}_t = (1-\phi)\frac{R_{t-1}}{R_t^F}$$

And $\Upsilon(\bar{\omega}_t)$ is the expectation of bank's portfolio shock conditional on not defaulting:

$$\Upsilon(\bar{\omega}_t) = \int_{\bar{\omega}_t} (\omega_t - \bar{\omega}_t) f_t(\omega_t) d\omega_t$$

These equations better allow to assess the role of capital requirements in the transmission of shocks that are not bank specific. Indeed, for all shocks ε_t the except bank risk shock:

$$\frac{\partial Z_t}{\partial \varepsilon_t} = \frac{1}{\phi}\Upsilon(\bar{\omega}_t)\frac{\partial R_t^F}{\partial \varepsilon_t} - \frac{R_t^F}{\phi}\frac{\bar{\omega}_t}{R_t^F}\frac{\partial R_t^F}{\partial \varepsilon_t}\Upsilon'(\bar{\omega}_t) = \frac{\Upsilon(\bar{\omega}_t) - \bar{\omega}_t \Upsilon'(\bar{\omega}_t)}{\phi}\frac{\partial R_t^F}{\partial \varepsilon_t}$$

[6]However, for many banks, risk weights are endogenous variables which follow probabilities of default. This simplification can still be justified: *(i)* the link between the probability of default and risk weights is not linear which would complexify the model; *(ii)* in reality, empirical probabilities of defaults are not equal to banks' estimate of default probabilities because of portfolio selection and optimization in their internal credit risk models; *(iii)* capital regulation allow prudential authorities to set additional capital buffer or risk weights by asset classes, which can then be regarded as an exogenous process.

It then becomes clear that capital requirements affect the transmission of macroeconomic shocks to banks returns through two channels. A direct channel goes through the denominator of the above ratio: the higher ϕ, the lower the share of loans in the balance sheet, the less sensitivity of banks balance sheets to loan returns. This suggests that capital requirements may act as automatic stabilizers across the business cycle. However, the indirect channel going through the numerator of the same ratio is more ambiguous. All other things being equal, the higher ϕ, the higher portfolio returns conditional on not defaulting, the higher the sensitivity to macroeconomic conditions. But in general equilibrium, ϕ also affect R_t^F (through the net worth channel and the credit supply channel), such that this indirect impact remains indeterminate. In addition, whether capital requirements acted as automatic stabilizers depends on the combination of shocks. The remaining of the paper clarifies this question for the 2021-2023 sequence by solving and estimating the model.

2.4 Public authorities

Government. The government levies lump-sum taxes $T_t = m^p T_t^p$ to finance the deposit insurance agency (DIA) and a stochastic flow of expenditures g_t. The budget is assumed to be balanced so that $T_t = T_t^{DIA} + P_t g_t$. Government expenditures follow the process $g_t = g e^{\zeta_{g,t}}$, with $\zeta_{g,t}$ following an $AR(1)$ process. We impose that in steady state $g/y = s_g$.

Deposit insurance agency. The DIA collects all payments from banks on the deposit market. The gross return on deposits from non-defaulting banks is recovered in full by the DIA. There is a fraction $1 - F_t^j(\bar{\omega}_t^j)$ of such deposits in the banking sector j. The remaining fraction is subject to default. In case of default, the DIA recovers the assets of the defaulting bank, net of a fraction μ^j due to recovery costs. The average default loss per unit of bank debt in sector j is thus

$$\Omega_t^j = \left(\int_0^{\bar{\omega}_t^j} f_{t+1}^j(\omega^j) d\omega^j \right) R_{t-1} - (1 - \mu^j) \left(\int_0^{\bar{\omega}_t^j} \omega^j f_t^j(\omega^j) d\omega^j \right) R_t^j \frac{B_{t-1}^j}{D_{t-1}^j}.$$

Let us define the aggregate average default loss per unit of bank debt

$$\Omega_t = \frac{d_{t-1}^M}{d_{t-1}} \Omega_t^M + \frac{d_{t-1}^F}{d_{t-1}} \Omega_t^F. \tag{2.9}$$

The DIA insures a fraction κ of deposits and then redistributes the recovered net assets to the depositors, so that

$$\tilde{R}_t = \kappa R_{t-1} + (1 - \kappa)(R_{t-1} - \Omega_t) = R_{t-1} - (1 - \kappa)\Omega_t.$$

It follows that the total cost for the DIA of insuring deposits, and hence the total amount of lump-sum taxes, is

$$T_t^{DIA} = \kappa \Omega_t d_{t-1}.$$

Monetary policy. The central bank sets the (gross) short term nominal interest rate R_t according to the following monetary policy rule

$$\log\left(\frac{R_t}{R_*}\right) = \rho_R \log\left(\frac{R_{t-1}}{R_*}\right) + (1-\rho_R)\left[a_\Pi \log\left(\frac{\Pi_t}{\Pi_*}\right) + a_y \log\left(\frac{GDP_t}{GDP_{t-1}}\right)\right] + \zeta_{R,t}, \tag{2.10}$$

where star values denote steady state counterparts, ρ_R measures the degree of interest rate smoothing, a_Π measures the reaction to inflation, a_y measures the reaction to GDP, and $\zeta_{R,t}$ a white noise shock.

3 Data and estimation

3.1 Data

Parameters are chosen so as to fit quarterly Euro Area data from 2002-Q1 to 2023-Q2. One distinctive feature of the period is the very low levels interest rates reached, such that the monetary authority may have have been constrained by an Effective Lower Bound (ELB). While we do not explicitly model this bound, nor the unconventional monetary tools used to circle it, we use as an observable the shadow rate of Krippner (2013, 2015), i.e. the hypothetical short-term interest rate if the ELB were not binding. This estimate thus enables us to study the role of capital requirements in the spectacular monetary tightening experienced in the EA since 2020.

The model is estimated so as to replicate business and financial cycles. We select 10 calendar and seasonally adjusted series with EA changing composition when available: GDP implicit price index, real GDP, real household consumption, a measure of the short-term shadow interest rate (Krippner, 2013, 2015), hours worked, real households' investment, real firms' investment, real credit to households, real credit to firms, and banks' default probabilities. All quantities are divided by the corresponding total population. Except the short-term interest rate and banks' probability of default, all variable are taken in demeaned log-difference, so as to focus on cyclical movements[7]. Banks' PD and the short-term interest rates are considered in deviation from their steady state value. All sources are reported in Table 1.

[7]The series of investment by non-financial corporates display some irregularities between 2015 and 2019 untied with macroeconomic conditions, and which can be linked to the national accounts of the Netherlands and Ireland. We withdraw their respective series from the EA series.

3.2 Calibrated parameters

A first subset of parameters is set prior estimation. Some are commonly used in the literature, while other are chosen to simultaneously match a series of steady-state moments. These parameters are presented in Table 2. Targeted moments and their theoretical counterparts are presented in Table 3.

- **Demographics:** The share of impatient households m_i corresponds to the share of households with debt (Finance and Network, 2013).

- **Preferences:** The inverse Frisch elasticity is set to 4 following Chetty et al. (2011) and Galí (2010). The labor disutility φ_p and φ_i are normalized to 1 as they only affect the size of the economy. The patient households discount rate is equal to 0.997 and targets the risk free rate.[8]

- **Production:** The markup rate is set to 20 %, thus $\mu = 1.2$. The depreciation rate of capital is set to 0.03. The capital share in production is set by $\alpha = 0.3$. The survival rate of entrepreneurs θ_e is set equal to 0.975 as in Gertler and Kiyotaki (2010). Transfers from households to entrepreneurs are used to match the NFC debt to GDP ratio. The standard deviation of idiosyncratic shocks affecting entrepreneurs, $\bar{\sigma}_e$, helps to match the default probability of NFC.

- **Government and monetary policy:** The share of final government expenditure s_g is directly set from the data.

- **Banks:** The share of insured deposits in bank debt κ is set to 0.54 following Demirgüç-Kunt et al. (2015). The parameter θ_b is used to match the price to book ratio of euro area banks denoted μ_b. Transfers from bankers χ_b are used to match the bank return on assets equity. Capital requirements are assumed to be static on our calibration period and according to Basel III standards. We set the broad based capital requirement ϕ to 10.5%. Risk weights γ^F and γ^H are set to respectively 0.35 and 1. σ_F is used to match banks' probability of default. Finally, the ratio between σ_F and σ_M which is not observed is set such that $\frac{PD_F}{PD_M} = \frac{\gamma^F}{\gamma^M}$, in order to ensure an appropriate sectoral capital requirement. Although banks granting mortgages are therefore less risky than their counterparts granting loans to businesses, household loans are not necessarily less risky than NFC loans.

- **Firms and households:** As it is impossible to target both the spread and default probability of respectively households and NFC at the steady state (as they depend on the same parameter), we target the spread. The non-targeted probability of default remains in accordance with

[8] See Iacoviello and Neri (2010) for a discussion on patient households discount factor.

data (see Table 3). [9]

- **Housing:** The depreciation rate of housing capital δ_h, the impatient households discount rate β_i, the housing utility scale factor for impatient households υ_i, the housing utility scale factor for patient households υ_p, the standard deviation for idiosyncratic shocks affecting households $\bar{\sigma}_i$ and the management cost ξ_s are set to target housing investment as a share of GDP, households loans' spread, housing as a share of capital held by patient households, households' credit as a share of GDP, households' loan to value and the capital held by household as a share of total capital.

3.3 Estimated parameters

The remaining parameters are estimated using a Bayesian approach, based on a first-order linearised version of the model and Kalman filtering. We use the Dynare toolbox (Adjemian et al., 2024). Prior and posterior distributions are reported in Table Table 4. As the model reports shocks in percent of their standard deviation, the estimated standard deviation is scaled in consequence.

Priors are set consistently with the literature on new-Keynesian models applied to EA data. For consumption habit, adjustment costs, price indexation and monetary policy rule, we follow Jondeau and Sahuc (2022), as their model also focuses on macro-financial interactions in the Euro Area. The prior for the taste shifter trend is set according to Galí et al. (2011). The prior mean for price rigidity is as Smets and Wouters (2003), but its standard deviation is relatively low. This is because the Covid period tends to push this parameter up, as the period displays a sizeable drop in consumption, but not so much of inflation. We thus constrain this parameter, in line with recent empirical studies on price rigidity in the EA before Covid (Gautier et al., 2022). Finally, we adopt an agnostic point of view regarding shocks by setting the same prior for all.

One distinctive feature of our estimates is the very low value attributed to habit formation compared to a similar literature (around 0.7), suggesting less inertia in consumption. However, this is partially balanced by the low value for the trend in the endogenous shifter compared to the model of Galí et al. (2011) without unemployment as observable: the marginal rate of substitution between labour and consumption puts more weight on past consumption. These two features seem to be related to the inclusion of the Covid period. A variant of the estimation until 2019-Q4 (although not completely comparable given the non-stationarity of the short-term interest rate over this sub-

[9] We compute targeted spreads between a composite interest rate on loans and the composite risk free rate. The composite loan interest rate is the weighted average of interest rates at each maturity range (up to 1 year, 1-5 years and over 5 years). The composite risk free rate is the weighted average of the following risk-free rates : 3 month EURIBOR (up to 1 year), German Bund 3 year yield (1-5 years), German Bund 7 year yield (over 5 years for NFC loans) and a weighted average of German Bund 7 year yield and German Bund 20 year yield (over 5 years for housing loans).

sample) yields a more standard combination of parameters. Adjustment costs are also relatively low for a similar reason, but remain in line with previous literature.

Other parameters are more standard compared to previous literature. Monetary policy parameters suggest that the shadow interest rate succeeds in capturing the unconventional monetary policy at the ELB. As in Christiano et al. (2014), risks shocks, be they for households, firms or banks, are the most persistent, along with shocks on total and labour productivity. The price mark-up shock has a high variance and is largely transitory, thus capturing high-frequency changes in inflation rate, as well as the relatively high exposure of EA to the price of imported goods. Other shocks (preference, government spending and adjustment costs) have more middle-range values.

3.4 Model evaluation

The resulting theoretical variance decomposition is presented in Table 5. One notable result is the low role of risk shocks. Most of the variation in macroeconomic aggregates are driven by more standard shocks, in particular the preference shock. This is partly linked to the fact that we use these shocks to target credit rather than spread, in order to replicate empirical variations of credit-to-GDP, as they of particular interest to macro-prudential policy makers. This is also the result of the estimation period, where macroeconomic shocks have played a particularly strong role. One could however question the low role played by the bank risk shocks, despite the inclusion of 2008-2009 in the estimation period and the direct observations of banks' probability of default. This is because EA banks' probability of default did not jump so much in 2008 than in 2011, during the sovereign debt crisis. Although this period is characterized by a lower than average growth rate, this is not a crisis period as 2008-2009 was. Therefore, risk shocks rather help match the middle-run effect of crisis, rather than their origins. Standard macroeconomic shocks are the main drivers of business and financial cycles in the model.

Table 6 presents some key empirical and theoretical moments. The strong variance in the data is rather well matched by the model for most of the variable. If GDP is empirically more volatile that what the model would suggest, this is the opposite for credit, partly because our model only includes one-period debt. The empirical covariance and autocorrelation are however further away from model-implied moments, notably well exemplifying the extraordinary nature of the Covid period. This also suggests that structural parameters have not been too much contaminated by the episode. We can still note that empirical autocorrelation are qualitatively in line with model-based autocorrelation, except for household credit which is far more persistent that the model would suggest - partly because we do not integrate house prices as an observable.

4 The anatomy of monetary tightening

To assess the effects of capital requirements in the macroeconomic impact of the 2021-2023 monetary tightening, we first recover the shocks that are at the origin of this unprecedented event. The eleven shocks all have different effects on inflation, interest rates and default probabilities, such that their combination may influence the effect of capital requirements: the origin of the shock matters.

4.1 Impulse response functions

Figure 1 plots the impulse response functions of the policy rate, inflation rate, GDP as well as the three probabilities of default to macroeconomic shocks. There are three supply shocks (total productivity, labour productivity, mark-up of intermediary good producers), two demand shocks (households' preference and government spending) and one monetary policy shock. Shocks are calibrated to generate a one percent increase in absolute value of the policy rate. Productivity shocks generate a more delayed increase in the policy rate compared to other shocks. Policy rate, firms' mark-up and labour productivity shocks reduce GDP, while inflationary government, preference and total productivity shocks generate an increase in GDP. Whatever the shock, banks' probabilities of default react less strongly than those of non-financial actors, a consequence of the assumption of perfect portfolio diversification. The mark-up shock and the monetary policy shock are the macroeconomic shocks that are are the most susceptible to generate financial stress. Uncertainty around the impact of these shocks remain limited. Productivity shocks are the one generating the most uncertainty.

Figure 2 plots the impulse response functions of the same variables to sectoral shocks. There are three risk shocks to firms' capital, impatient households' housing and banks' portfolio. They are completed by two demand shocks on investment adjustment costs, for productive capital and housing. An increase in NFC and household risk gives rise to deflationary pressures, while an increase in banks' risk generates inflationary pressures as it creates a situation of over production. A decrease in capital and housing adjustment cost first decreases GDP, as firms face more demand, before increasing it as firms can adjust more easily. This creates inflationary pressures, and thus a rise in the policy rate.

4.2 Historical decomposition

These shocks enable to capture the origins of the empirical variations in inflation, interest rate and GDP. Figure 3 plots the decomposition of the policy rate, in deviation from its steady state value. The rise of interest rates of 2006-2007 is thus mainly explained by positive supply (total productivity shocks) and demand (positive preference shocks) factors. The sudden decrease of

2008 is mostly explained by a negative investment shocks, supplemented by a particularly aggressive monetary policy. The low rate environment that followed is then explained by a reversal in supply side cycles, with strong and persistent negative productivity shocks, supplemented by negative preference shocks. At the beginning of this sub-period, decrease in firms' mark-up as well as government policy shock are the only inflationary pressures that contribute positively to GDP. Starting from 2016, total productivity starts to recover, but labour productivity and government spending firms' mark-up decrease, maintaining interest rates at a low level.

The Covid period set the seed of inflationary pressures, with sizeable cost-push shocks countered by negative demand shocks. However, once the latter receded, inflationary pressures did no disappear. The mark-up shock left the stage for decrease in the adjustment cost of investment, which contributed positively to GDP and inflation. This shock stands for sharp decrease in the relative price of tangible assets in 2021-2023, as consumption prices rose more than investment prices, thus giving firms an incentive to invest and leading to over demand in the final good market. As this shock is persistent and expansionary, it warrants a stronger reaction of monetary policy compared to a cost-push shock, which is short-lived and recessionary.

The decomposition of year-on-year inflation is plotted in Figure 4 and shows notably the action of monetary policy on inflation. While monetary policy appears relatively tight until 2012, expansionary shock are the norm between 2014 and 2019 to fight below average inflation. However, once deflationary pressures disappeared after Covid, past accommodative monetary policy continued to push inflation up, and despite the exogenous increase in the policy stance exemplified in Figure 3. Figure 5 plots the decomposition of year-on-year GDP growth, and show that these shocks brought down GDP growth below its average in 2023, starting from the strong post-Covid context driven by positive demand shocks.

This decomposition thus indicates that the strong rise in interest rates of 2021-2023 finds its roots in mostly supply-side shocks, complemented by a positive demand shock and the lagged effect of accommodative monetary policy, with an overall ambiguous effect on GDP. We recover this combination of shocks to assess how the level of capital requirements affected their transmission in the EA.

5 Capital requirements and the transmission of monetary tightening

5.1 Basel III and monetary tightening

To what extent may capital requirements affect the transmission of monetary tightening? European prudential authorities have increased capital requirements in the 2010's by going from Basel II to Basel III. In particular, the minimum 8% of Risk-Weighted Assets (RWA) capital requirement of Basel II was completed by an additional 2.5% of conservation buffer (CCoB). This new prudential environment motivates to re-examine the effects of a monetary tightening on financial stability. On the one hand, these higher buffers provide more resilience capacity to banks when facing a shock. On the other hand, by constraining lending in times of crisis, they may amplify the effects of the shock. This section assesses the effects of higher capital requirements (by 2.5 p.p.) on the transmission of the 2021-2023 inflation surges and monetary tightening in the Euro Area, by building a counterfactual scenario where capital requirements remained at 8 % of RWA.

Figure 6 reports the probability of default of banks under two scenarios: (i) the sum of all estimated shocks between Q2 2021 and Q2 2023 under Basel III regulation (black line) and (ii) the same shocks under Basel II regulation (dashed red line). Higher capital requirements, under Basel III, limit the volatility of banks' probability of default. Under Basel II, the inflationary surge and monetary tightening would have led to a higher deviation of banks' probability of default from its long-term trend by 100 bps.

Therefore, capital requirements do not need to be countercyclical to be efficient: in an inflationary context, they act as automatic stabilizers, by limiting the amplitude of expansionary as well as recessionary shocks. In Figure 7 and Figure 8, the black line shows the difference between the reaction of macroeconomic and financial variables under Basel III relative to Basel II. The colored bars show the contribution of each shock to this difference. The contribution of the bank' risk shock dominates in explaining the difference between Basel III and II. As shown in Figure 3, the banks' risk shock contribute negatively to the evolution of the interest rate in the period of concern. Figure 7 shows that, with Basel III, the interest rate was higher during the post-Covid period and lower in the beginning of 2023 than it would have been under Basel II. During the post-Covid period, higher capital requirements imply higher inflation as aggregate supply was moderated by lower credit supply and lower net worth for savers, weighting more on GDP. However, at the start of 2023, aggregate supply decreased relatively less because credit supply remained resilient, meaning higher supply relative to demand, thus lowering inflation and the policy rate. Therefore, higher capital requirements moderate the expansion and support credit in the period of contraction. While the impact on inflation and interest rate is mainly driven by the bank' risk shock, capital investment shock contributed negatively to the efficiency of capital requirements, by constraining credit supply and mitigating its expansionary impact. AT the end of the period, higher capital requirements protected the economy from the negative effect of banks' risk shock on consumption and investment. Capital requirements also appear important to limit the negative effect of the mark-up shock on consumption and to stimulate capital investment by downplaying the rise of the policy rate.

The same automatic stabilizer mechanism applies for asset prices, as Basel III constrained lending in periods of expansion, but expanded it in periods of contraction. During the expansion, to maintain its capital requirements, banks adapted their lending policy by cutting lending and by raising spreads in an effort to increase retained earnings, sharing the cost of capital requirements with borrowers. Figure 8 shows that higher capital requirements implied lower capital and house prices during the post-Covid recovery but relatively higher asset prices when banks' risk increased at the end of the period due to higher constraint on credit supply during the recovery but lower during the risky period.

Households and NFC risk was slightly affected by higher capital requirements. While the higher capital requirements of Basel III were costly during the post-Covid recovery, they limited households' and NFC' risk as households and NFC were less leveraged during this period. On the contrary, by supporting credit supply in periods of expansion, higher capital requirements implied a slightly higher probability of default for borrowers.

Effects were quantitatively higher for firms than for households. During the 2022 expansion, effects were stronger on credit supply and spreads for NFC than households because risk weights were higher for NFC. In addition, the investment and firm risk shocks, which played an important role in the unfolding of monetary tightehing, had a more direct impact on firms than on households. However, housing investment dropped more than business investment. Investment was not only determined by credit supply but also demand. As patient households bore the cost of bank's losses, they also reduced their demand of housing. When borrowing costs increased, households reduced relatively more their housing investment than firms attenuated their NFC investment. This effect was amplified by another channel : capital requirements also affected assets' demand from savers through banks' profitability.

In conclusion, the sudden rise in interest rates could have generated a great impact through risk shocks. Indeed, as discussed in Hoffmann et al. (2019), the effect of a monetary tightening can transmit via the balance sheet channel or via borrowers' balance sheet, with consequences for consumption and investment. The potential materialization of these risks depends on who bears the interest rate risk. In particular, leveraged actors could have seen their debt capacity restrained if they were imperfectly hedged against interest risks, or if they had concentrated portfolios. However, our historical decompositions give a relatively low role to these shocks in 2023, as capital requirement were sufficiently high in face of a rather limited shock. The gains from higher capital requirements would have been higher in case of larger bank risk shock, similar to the one estimated for 2011 for instance.

5.2 Redistributive effects of capital requirements

As suggested in the previous subsection, the mitigating impact of capital requirements went through both savers' net worth and borrowers' credit constraints. This also means that capital requirements had strong heterogenous effets between savers and borrowers. Figure 9 shows the differential evolution of each household's choice variable under Basel III and Basel II regulations. We see for instance that under Basel III the evolution of savers' consumption is higher by slightly more than 0.1 percentage points in 2023-Q1. More general, higher capital requirements smoothed savers' consumption, a result which is largely driven by the banks' risk shock: when banks' risk was low, capital requirements penalized their profitability, hence savers income flow. However, when banks' risk materialized, the opposite happened, fostering savers' consumption. On the other hand, borrowers consumption was impeded by capital requirements at the time the bank risk shock hit: higher capital requirements protected banks' owners rather than their borrowers. However, the contribution of capital requirements remained positive at the end of the period and after banks risk shocks vanished. By protecting banks, capital requirements ensured a faster recovery. Deposit insurance, whose cost is financed by patient households, already smoothed the effects of the shocks and were complemented by capital requirements, by limiting the cost paid by households.

Regarding housing, capital requirements enabled to maintain borrowers access to housing, whose growth rate was 0.1 percentage points higher in 2023-Q1. Note that the role of nearly each shock is inverted between savers and borrowers. For instance, while capital requirements reinforced the negative impact of monetary policy shocks on savers' housing, it mitigated it for borrowers. However, the effects of capital requirements on housing investment are roughly five time higher for savers than borrowers, highlighting that capital requirements affect macroeconomic dynamics mostly through savers' net worth.

Finally, it is noticeable that capital requirements have no economically significant heterogeneous effects on the amount of hours worked of both households. This is because short-run wealth effect are very low, such that the only driver of hours worked is labour demand and not supply. As both households face the same demand, capital requirements has no heterogeneous effect.

These heterogeneous and redistributive effects of capital requirements partly explain the differences in macroprudential stances across EA countries: countries with a higher share of borrowers have less incentive to increase capital requirements above Basel III minima.

5.3 Macroprudential policies and monetary tightening

In recent years, many European macroprudential authorities have risen the risk weights for mortgages. In this section, we analyse the effects of the rise of sectoral mortgages risk-weights. This allows us to discuss the effects of lower risk-weight for households relative to other factors in the recent period. We adopt a conservative approach, where banks' ratio of equity to RWA remains at its pre-crisis level during the whole crisis. Indeed, although banks are allowed to dip into these buffers in times of stress, past experience suggested they do not, because of market stigma or as they anticipate that these buffers will have to be rebuilt[10].

Figure 10 shows the reaction of probabilities of default to 2 different scenarios: (i) sectoral capital requirements: total capital requirements are at Basel III level (10.5 %) and the authority increased mortgage risk-weight from 35 % to 100 % and (ii) general capital requirement: the authority increased total capital requirements from 10.5 % to 11.5 %. The two scenarios imply costs in the first year and gains in the end of period in terms of banks' probability of default and thus GDP.

However, sectoral capital requirement are more efficient at stabilizing GDP. They counter the distortion introduced by differential risk weights, and reallocate bankers' portfolios towards NFC. Indeed, they lead to a substitution effect such that banks finance more NFC investment. Overall, this policy reduces the cost of capital requirements in terms of GDP when it came to the post-Covid investment catch-up.

With the scenario (ii) of higher total capital requirements (red dashed line), the cost-benefit analysis is less favourable. This is linked to the contribution of capital requirements on capital investment, driven by post-Covid investment catch-up. Compared to a sectoral capital requirement, the general capital requirement has a less negative impact on consumption and housing investment, but it limits even more business investment. This results exemplifies that high capital requirements can affect asymetrically housing and investment in the context of estimated shocks. However, this option is also interesting as financial variable are much less volatile and could be preferred by households as their consumption and ability to invest in housing is less affected.

Previous results do not capture the full benefits of higher ex-ante capital requirement in case of bank' risk shock. Indeed, capital requirements built ex-ante help the economy to recover faster

[10] See ECB macroprudential bulletin.

from banks' risk shocks as credit begins to flow back more readily (Jordà et al., 2021). We leave this question to further research.

6 Conclusion

This paper built a new Keynesian model with a rich set of financial frictions to study the propagation of monetary tightening on a large set of financial variables. We then demonstrated that while banks' capital requirement limited post-Covid growth, they successfully prevented the materialization of risks when the ECB rose short-term interest rates. By smoothing the reaction of banks' net worth to economic conditions, they act as automatic stabilizers and reduce the probability of a hard landing. In addition, they slightly downplayed the rise in inflation. Overall, they turned out to be complementary to monetary policy. Therefore, in a case of an unprecedented monetary tightening, capital requirements do not necessarily need to be countercyclical to be efficient. Their impact is however heterogeneous between savers and borrowers, and hence between Euro Area member states, such that this lets some room for cross-country heterogeneity regarding macroprudential polices.

However, if capital requirements limited the possibility of a hard landing in case interest risks are borne by banks, they are not sufficient to ensure by themselves financial stability. Indeed, by highlighting that capital requirements enhanced banks' resilience, this paper showed that such policies, up to a point, in fact increase the indebtedness of private agents. Other macroprudential tools, such as borrower-based measures, can then be complementary, by ensuring sound financing conditions and an appropriate level of indebtedness before entering a monetary tightening episode.

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A Figures and tables

Table 1: Data sources

Series	Source
Shadow short-term interest rate	Krippner (2013, 2015)
3-month Euribor	ECB, FM, Q.U2.EUR.RT.MM.EURIBOR3MD_.HSTA
Implicit GDP price index	Eurostat, MNA, Q.PD15_EUR.SCA.B1GQ.EA
Real GDP	Eurostat, MNA, Q.CLV15_MEUR.SCA.B1GQ.EA
Real household consumption	Eurostat, MNA, Q.CLV15_MEUR.SCA.P31_S14_S15.EA
Nominal households' investment	ECB, QSA, Q.Y.I9.W0.S1M.S1.N.D.P51G._Z._Z._Z.XDC._T.S.V.N._T
Nominal firms' investment	ECB, QSA, Q.Y.I9.W0.S11.S1.N.D.P51G._Z._Z._Z.XDC._T.S.V.N._T
Hours worked	ECB, ENA, Q.Y.U2.W2.S1.S1._Z.EMP._Z._T._Z.HW._Z.N
EA population (changing composition)	ECB, ENA, Q.N.U2.W0.S1.S1._Z.POP._Z._Z._Z.PS._Z.N
EA 20 population (fixed composition)	ECB, ENA, Q.N.I9.W0.S1.S1._Z.POP._Z._Z._Z.PS._Z.N
Nominal credit to households	ECB, BSI, Q.U2.N.A.A20.A.1.U2.2250.Z01.E
Nominal credit to firms	ECB, BSI, Q.U2.N.A.A20.A.1.U2.2240.Z01.E
Real house prices	OECD, House prices, Q.EA.RHP
Banks' 5-year CDS premium	Bloomberg, conversion into default probabilities (40% recovery rate)
Return on equity, Banks	ECB, CBD2, Q.U2.W0.57._Z._Z.A.A.I2003._Z._Z._Z._Z._Z._Z.PC
Price to book ratio of banks	Datastream.
General government final consumption expenditure (% GDP)	Eurostat, Government revenue, expenditure and main aggregates, A.PC_GDP.S13.P3.EA19
Nominal GDP	ECB, MNA, Q.N.U2.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.V.N
Household interest rate	ECB, MIR, M.U2.B.A2C.A.R.A.2250.EUR.N
NFC interest rate	ECB, MIR, M.U2.B.A2A.A.R.A.2240.EUR.N
Lending for house purchases : up to 1 year	ECB, BSI, M.U2.N.A.A22.F.1.U2.2250.Z01.E
Lending for house purchases : over 1 year and up to 5 years	ECB, BSI, M.U2.N.A.A22.I.1.U2.2250.Z01.E
Lending for house purchases : over 5 years	ECB, BSI, M.U2.N.A.A22.J.1.U2.2250.Z01.E
Loans to NFC : up to 1 year	ECB, BSI, M.U2.N.A.A20.F.1.U2.2240.Z01.E
Loans to NFC : over 1 year and up to 5 years	ECB, BSI, M.U2.N.A.A20.I.1.U2.2240.Z01.E
Loans to NFC : over 5 years	ECB, BSI, M.U2.N.A.A20.J.1.U2.2240.Z01.E
Euribor 3 month	ECB, FM.M.U2.EUR.RT.MM.EURIBOR3MD_.HSTA
German bond 3 years	ECB, FM.B.DE.EUR.RT.BB.DE3YT_RR.YLD
German bond 7 years	ECB, FM.B.DE.EUR.RT.BB.DE7YT_RR.YLD
German bond 20 years	ECB, FM.B.DE.EUR.RT.BB.DE20YT_RR.YLD
Bank loans in NFC total debt	BDF, CFT, Q.S.I8.W0.S11.S1.N.L.LE.F401.T._Z.XDC_R_DEBT._T.S.V.N._T

Table 2: Preset and calibrated parameters

	Parameter	Value
Panel A: preset parameters		
Inverse Frisch elasticity	η	4
Patient disutility of labor	φ^p	1
Impatient disutility of labor	φ^i	1
Bank M bankruptcy cost	μ_M	0.3
Bank F bankruptcy cost	μ_F	0.3
NFC bankruptcy cost	μ_e	0.3
HH bankruptcy cost	μ_i	0.3
Share of insured deposits in bank debt	κ	0.54
Consumption smoothing	ψ	0.5
Productivity	A	1
Capital share in production	α	0.3
Depreciation rate of capital	δ_K	0.03
Survival rate of entrepreneurs	θ_e	0.975
Capital requirements for bank F	ϕ_F	0.105
Panel B: calibrated parameters		
Impatient household discount rate	β_i	0.983
Patient household discount rate	β_p	0.997
Housing depreciation rate	δ_h	0.008
Patient housing scale factor	υ_p	0.049
Impatient housing scale factor	υ_i	0.590
Management cost	ξ_s	0.004
Survival rate of bankers	θ_B	0.873
Std. idiosyncratic shocks, bankers *M*	$\bar{\sigma}_M$	0.013
Std. idiosyncratic shocks, bankers *F*	$\bar{\sigma}_F$	0.043
Std. idiosyncratic shocks, entrepreneurs	$\bar{\sigma}_e$	0.361
Std. idiosyncratic shocks, HH	$\bar{\sigma}_i$	0.353
Banker's endowment	χ_b	0.81
Entrepreneur's endowment	χ_e	0.377
Capital requirements for bank M	ϕ_M	0.037

Table 3: Calibration targets

	Target	Model
Indebted households share m_i	0.44	0.44
Final gov. consumption exp. s_g	0.21	0.21
Risk free rate $\bar{r}$	1.16 %	1.20 %
Yearly inflation rate	1.72%	1.72 %
Return on asset equity	11.42 %	11.42 %
Housing investment as a share of GDP	0.06	0.06
HH loans to (quarterly) GDP	1.98	2.00
Housing among households capital	0.61	0.58
NFC loans to (quarterly) GDP	1.68	1.81
Banks default rate	1.28 %	1.27 %
Price to book ratio μ_b	1.15	1.19
Loan to value	37.3 %	37.7 %
Capital share of households	0.15	0.16
Spread NFC loans	1.34	1.46
Spread Households loans	1.07	1.05
NFC default rate (untargeted)	2.5 %	1.6 %
HH default rate (untargeted)	1 %	2 %

Table 4: Estimated parameters

		Prior distribution			Posterior distribution	
		Dist.	Mean	Std.	Mean	Std.
Panel A: structural parameters						
Endogenous taste shifter	ζ_J	Beta	0.5	0.2	0.0330	0.0677
Habits	ψ	Beta	0.4	0.1	0.1133	0.0409
Housing adjustment cost	ψ_H	Gamma	4	1	3.9328	0.8890
Capital adjustment cost	ψ_K	Normal	4	1	2.6607	0.5610
Price rigidity	ξ	Beta	0.75	0.025	0.8605	0.0122
Price indexation	ι	Beta	0.4	0.1	0.2619	0.0863
Monetary policy smoothing	ρ_R	Beta	0.8	0.1	0.8422	0.0147
MP reaction to inflation	a_Π	Normal	1.7	0.1	2.0056	0.0958
MP reaction to GDP growth	a_y	Normal	0.125	0.05	0.1340	0.0361
Panel B: shocks standard deviation						
Total productivity	σ_a	Inv. Gam.	0.5	2	3.1446	0.8709
Labour productivity	σ_z	Inv. Gam.	0.5	2	0.8122	0.0625
Mark-up	σ_μ	Inv. Gam.	0.5	2	22.4343	3.3160
Housing adjustment	σ_{i_H}	Inv. Gam.	0.5	2	3.2059	0.2625
Capital adjustment	σ_{i_K}	Inv. Gam.	0.5	2	4.6598	0.4511
Monetary policy	σ_R	Inv. Gam.	0.5	2	0.1452	0.0133
Government spending	σ_g	Inv. Gam.	0.5	2	1.9221	0.1511
Preference	σ_c	Inv. Gam.	0.5	2	2.3103	0.2455
NFC risk	σ_e	Inv. Gam.	0.5	2	2.1963	0.2585
HH risk	σ_i	Inv. Gam.	0.5	2	1.2645	0.1559
Bank risk	σ_B	Inv. Gam.	0.5	2	4.0536	0.3170
Panel C: shocks autocorrelation						
Total productivity	ρ_a	Beta	0.5	0.2	0.9050	0.0340
Labour productivity	ρ_a	Beta	0.5	0.2	0.9374	0.0217
Mark-up shock	ρ_μ	Beta	0.5	0.2	0.0680	0.0519
Housing adjustment shock	ρ_{i_H}	Beta	0.5	0.2	0.5832	0.0567
Capital adjustment shock	ρ_{i_K}	Beta	0.5	0.2	0.7336	0.0415
Government spending shock	ρ_g	Beta	0.5	0.2	0.5646	0.0833
Time preference shock	ρ_c	Beta	0.5	0.2	0.4024	0.0982
NFC risk shock	ρ_e	Beta	0.5	0.2	0.9563	0.0250
HH risk shock	ρ_i	Beta	0.5	0.2	0.9733	0.0216
Bank risk shock	ρ_B	Beta	0.5	0.2	0.8974	0.0366

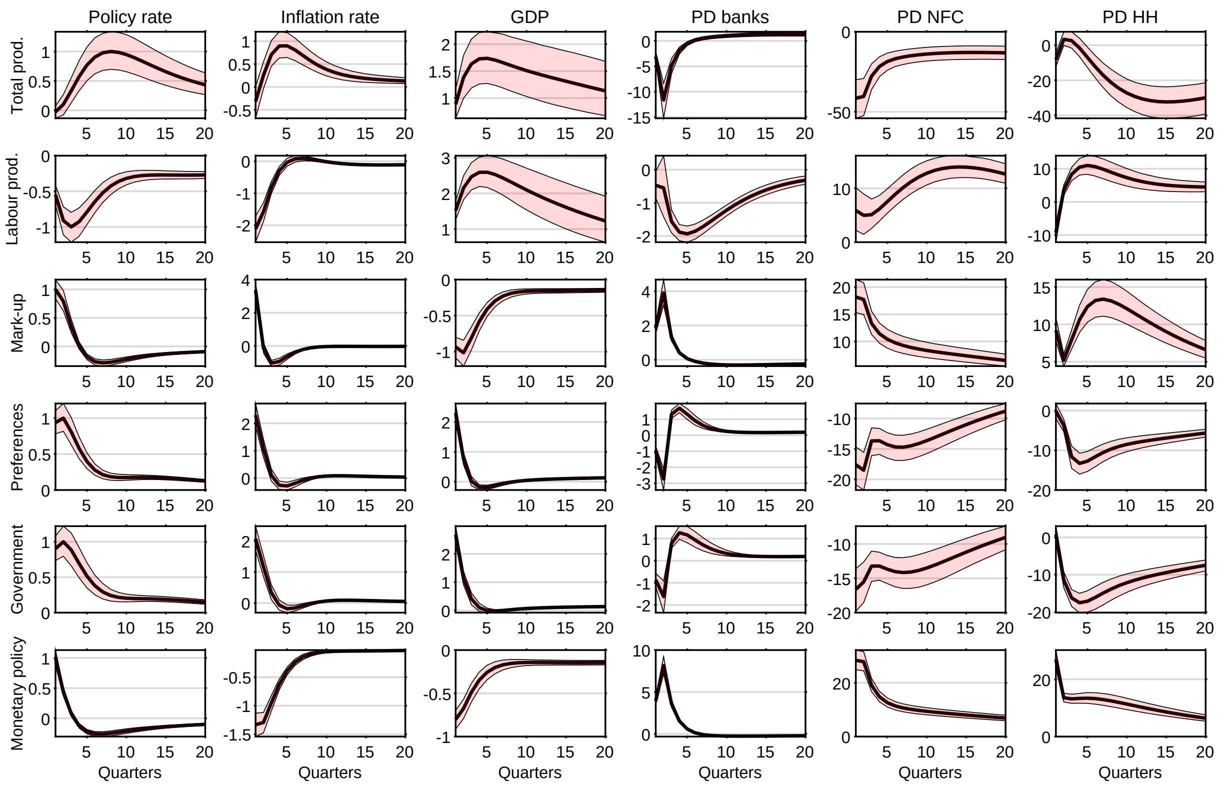
Table 5: Variance decomposition, in percent

	σ_a	σ_z	σ_μ	σ_{i_K}	σ_{i_H}	σ_R	σ_g	σ_c	σ_e	σ_i	σ_B
GDP	4.25	4.47	8.02	14.81	1.21	4.69	6.96	55.44	0.06	0.05	0.05
Consumption	0.45	3.01	6.26	1.22	0.08	4.43	0.22	84.18	0.05	0.07	0.03
Hours worked	3.96	5.24	8.07	13.34	1.19	4.08	7.12	56.32	0.13	0.01	0.53
Policy rate	25.17	6.75	11.98	27.04	0.3	7.59	1.89	15.95	1.09	0.39	1.86
Inflation rate	6.85	4.72	41.79	13	0.19	12.63	1.62	18.02	0.31	0.11	0.78
NFC investment	14.14	1.81	3.15	78.11	0.05	1.23	0.06	0.55	0.86	0.02	0.02
HH investment	4.5	6.25	1.56	9.54	75.12	0.6	0.1	1.12	0.65	0.41	0.15
NFC credit	8.52	0.59	6.94	9.74	0.15	2.37	0.19	5.95	59.91	4.3	1.33
HH credit	5.71	1.02	16.43	2.71	0.72	7.9	0.09	2.1	11.53	51.16	0.64
PD banks	0.22	0.01	0.05	0.05	0	0.17	0	0.03	0.99	0.11	98.36

Table 6: Data and model moments

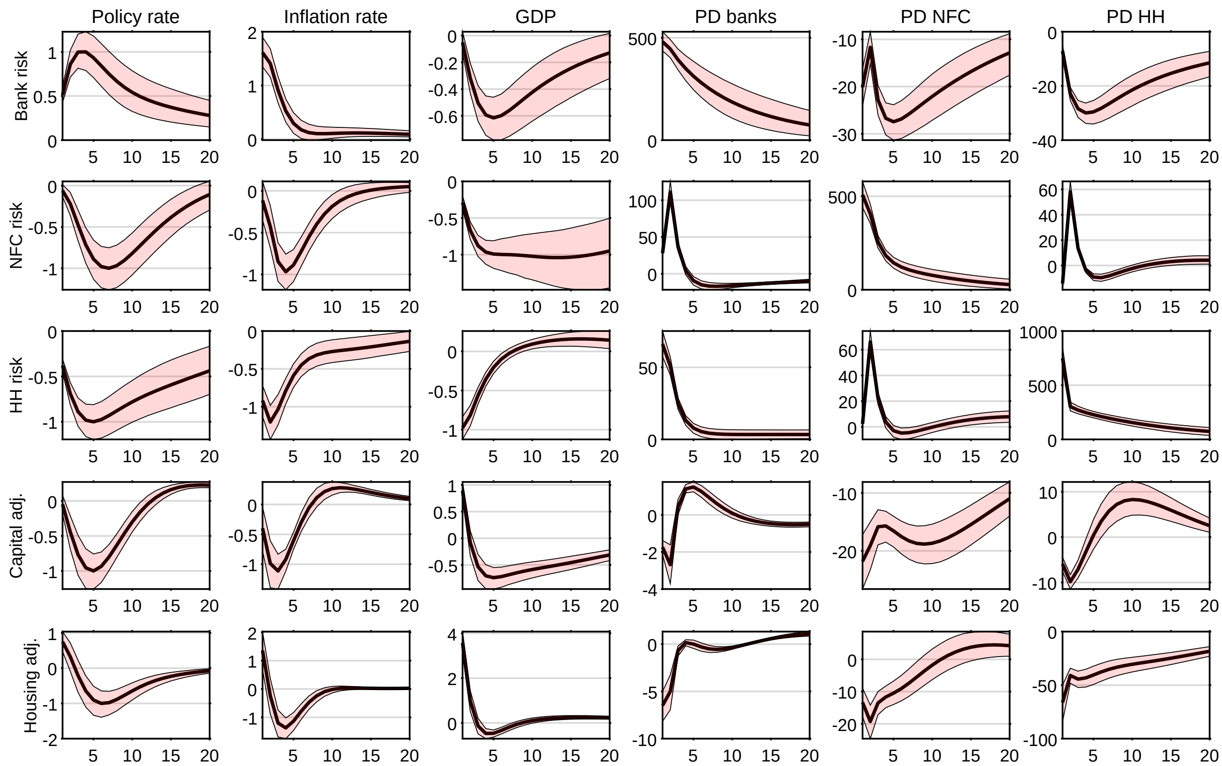
	Data	Model	
		Mean	90% CI	
Panel A: variance				
GDP	3.85	2.54	1.99	3.06
Consumption	5.08	5.54	3.95	7.22
Hours worked	5.03	4.84	3.74	5.84
MP rate	5.13	4.07	2.75	5.16
Inflation	0.17	0.41	0.3	0.5
NFC investment	12.04	17.91	13.07	23.07
HH investment	10.8	11.94	9.45	14.61
NFC credit	1.76	2.51	2.09	3.04
HH credit	0.92	3.4	2.75	4.01
PD banks	1.39	1.09	0.51	1.66
Panel B: covariance with GDP				
Consumption	4.22	3.09	2.18	3.98
Hours worked	4.26	3.24	2.47	3.98
MP rate	-0.11	-0.24	-0.42	-0.03
Inflation	-0.35	0.04	-0.08	0.17
NFC investment	5.23	3.22	2.43	4.03
HH investment	5.3	0.93	0.73	1.12
NFC credit	0.04	-0.27	-0.49	-0.08
HH credit	0.75	0.91	0.7	1.12
PD banks	-0.25	-0.03	-0.04	-0.02
Panel C: first-order autocorrelation				
GDP	-0.22	-0.13	-0.2	-0.07
Consumption	-0.31	-0.2	-0.26	-0.13
Hours worked	-0.28	-0.18	-0.24	-0.13
MP rate	0.97	0.89	0.86	0.93
Inflation	0.35	0.45	0.36	0.54
NFC investment	-0.2	0.17	0.04	0.3
HH investment	-0.06	0.14	0.01	0.28
NFC credit	0.64	0.5	0.46	0.54
HH credit	0.5	-0.01	-0.03	0.02
PD banks	0.93	0.89	0.84	0.95

Figure 1: Impulse response to macroeconomic shocks



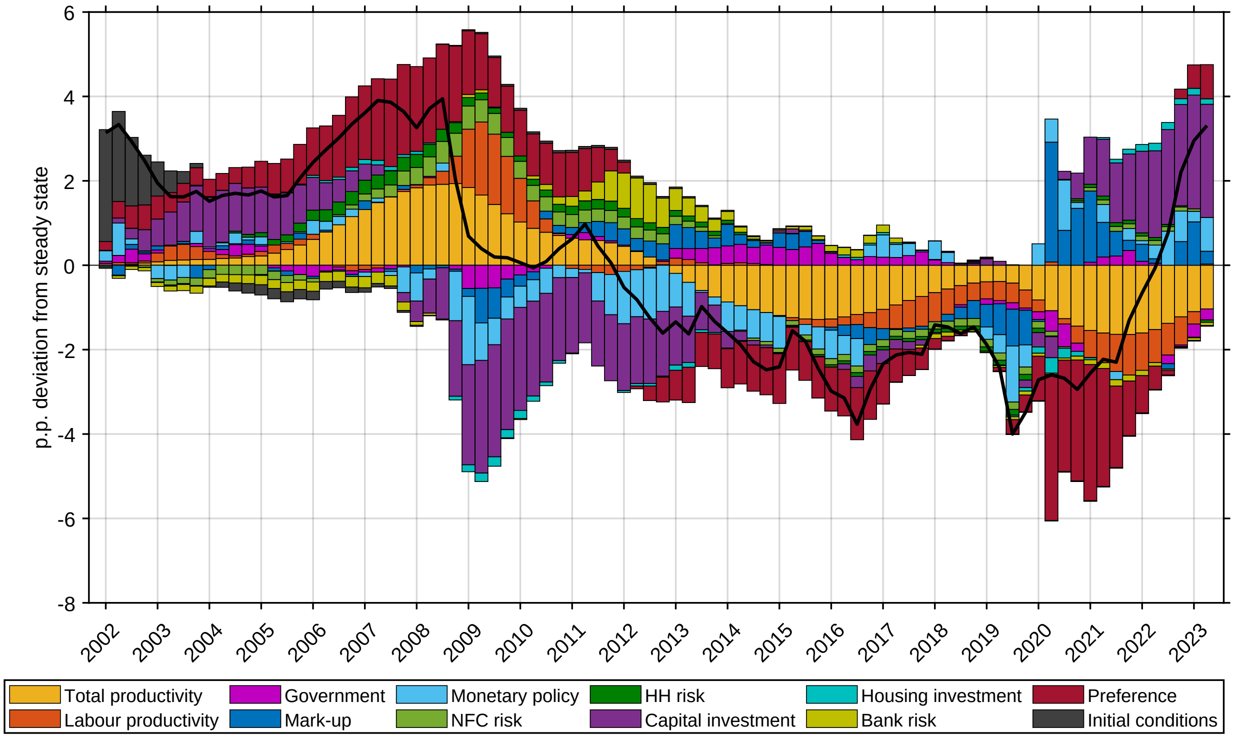
Notes. All variables are expressed in deviation from their steady state in percentage points for policy rate and inflation rate, in percent for GDP, and in basis points for probabilities of default. Shocks are all calibrated to generate a one percent increase of the policy rate in absolute value. 90% confidence intervals are based on 2,000 simulated draws from the parameter distributions.

Figure 2: Impulse response to sectoral shocks



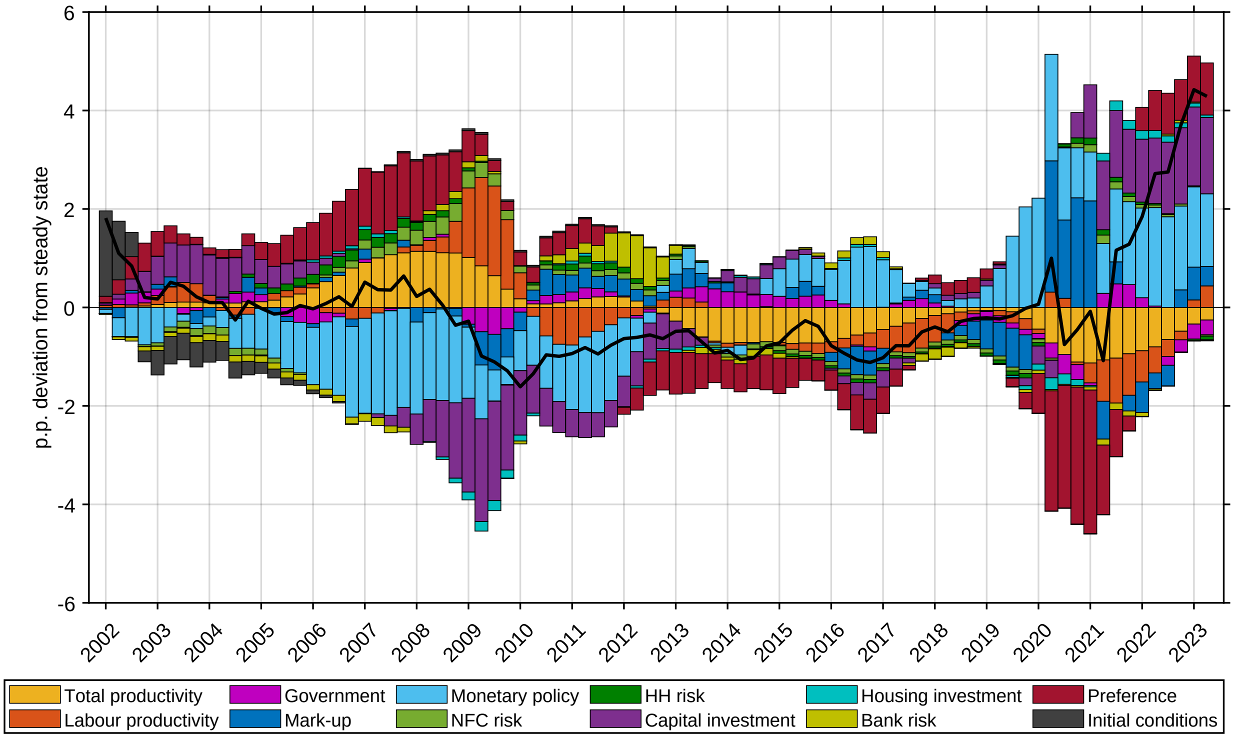
Notes. All variables are expressed in deviation from their steady state in percentage points for policy rate and inflation rate, in percent for GDP, and in basis points for probabilities of default. Shocks are all calibrated to generate a one percent increase of the policy rate in absolute value. 90% confidence intervals are based on 2,000 simulated draws from the parameter distributions.

Figure 3: Decomposition of short-term interest rate



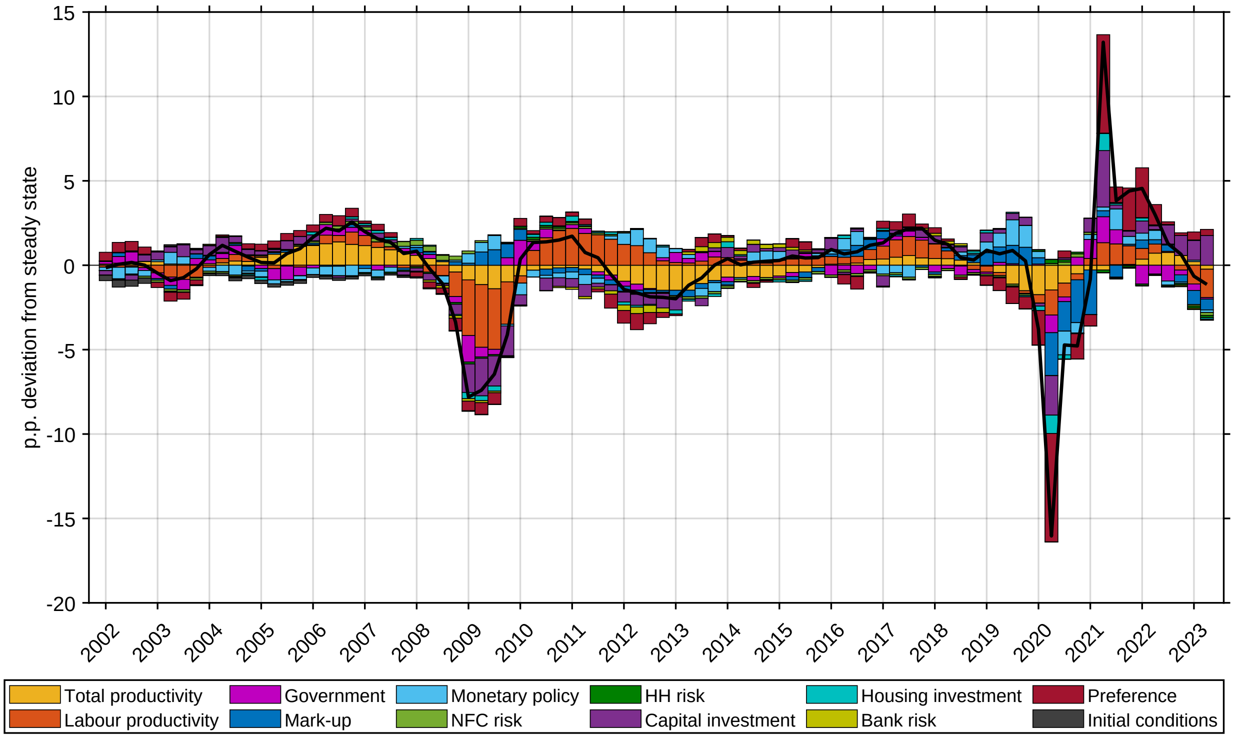
Notes. Deviations from steady state in percentage point.

Figure 4: Decomposition of year-on-year inflation rate



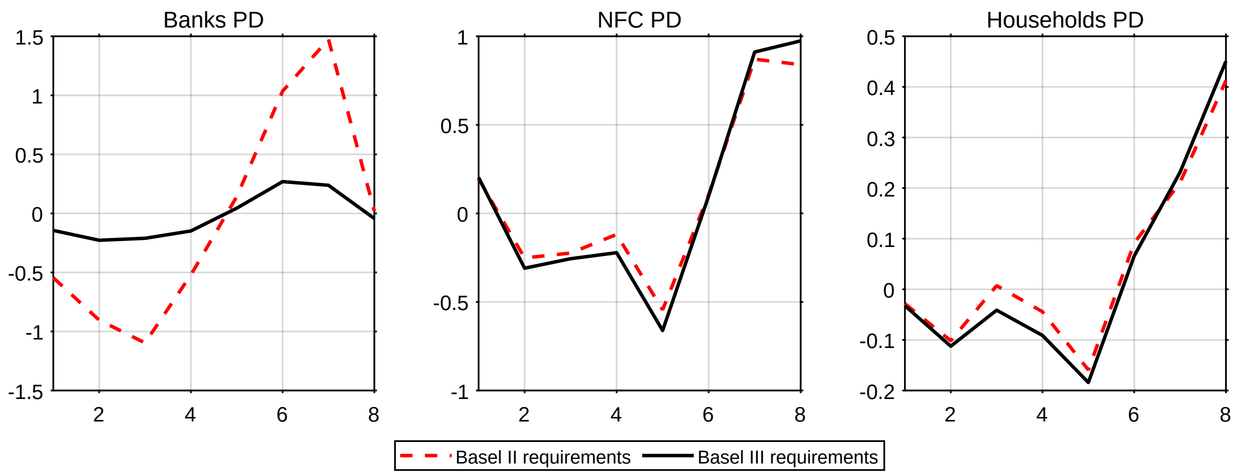
Notes. Deviations from steady state in percent.

Figure 5: Decomposition of year-on-year GDP growth rate



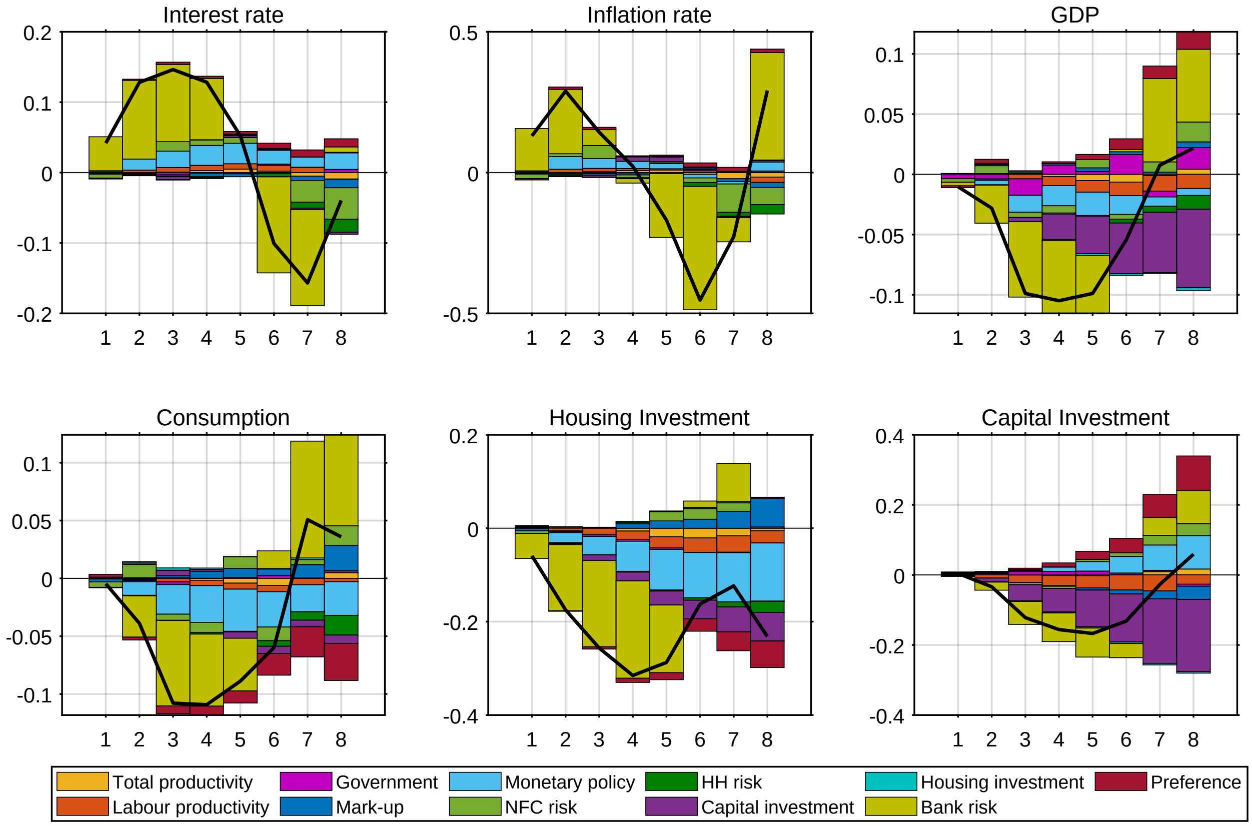
Notes. Deviations from steady state in percent.

Figure 6: Probabilities of default: Basel III vs Basel II capital requirements



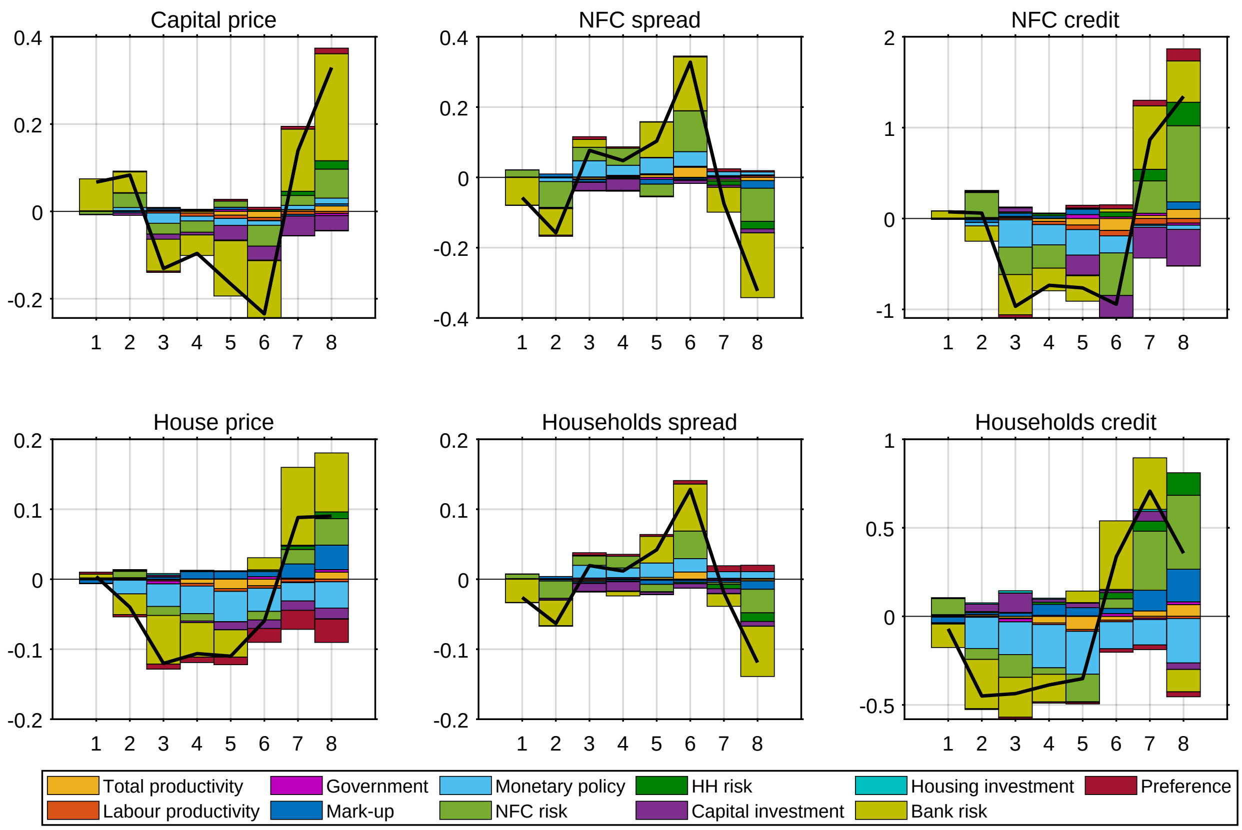
Notes. The y-axis represents deviations from steady state in percentage point. The x-axis represents quarters, the first one being Q3 2021.

Figure 7: Impact of Basel III from 2021-Q2 to 2023-Q2 - Macroeconomic variables



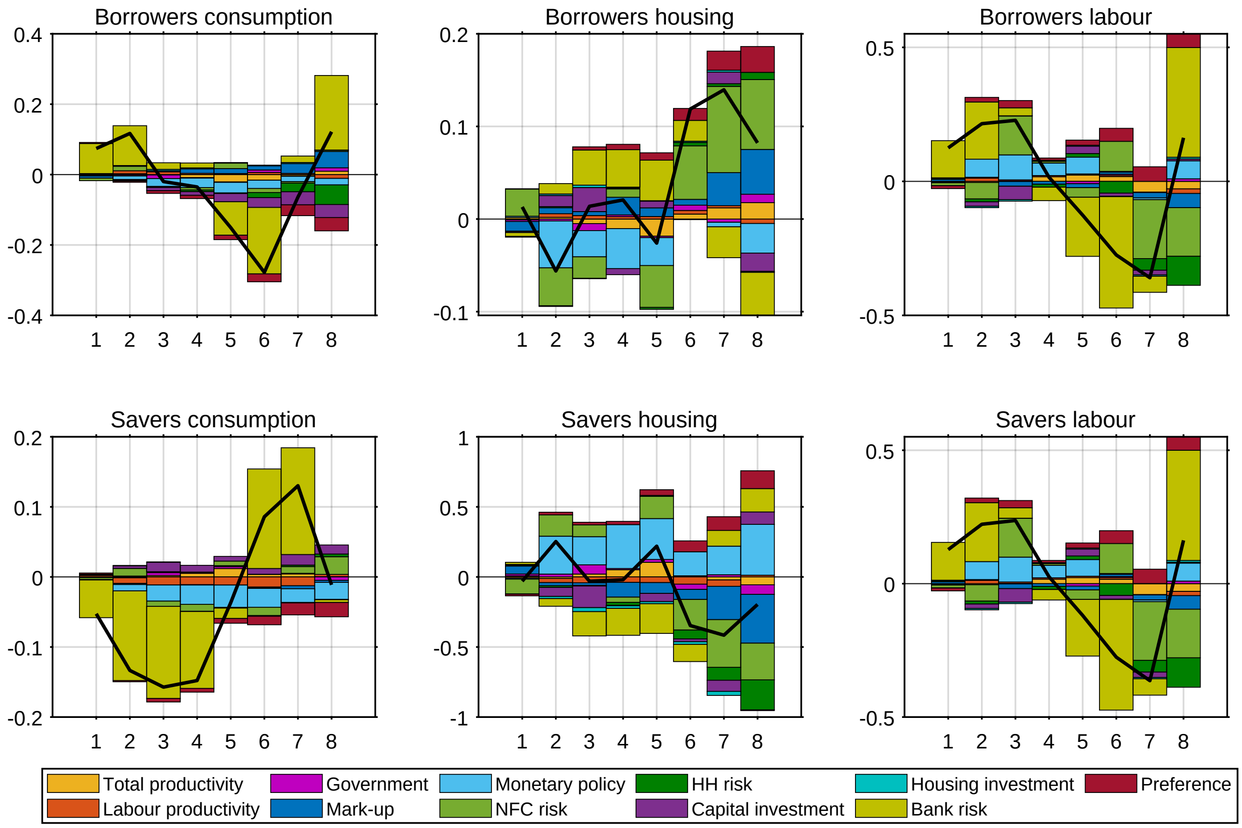
Notes. The black line presents the difference between the actual path minus the counterfactual path. Colours presents the contribution of each shock to this overall impact. The x-axis represents quarters, the first one being Q3 2021. All variables are in deviation from steady state in percent, except the interest rate and the inflation rate, which are in percentage point.

Figure 8: Impact of Basel III from 2021-Q2 to 2023-Q2 - Financial variables



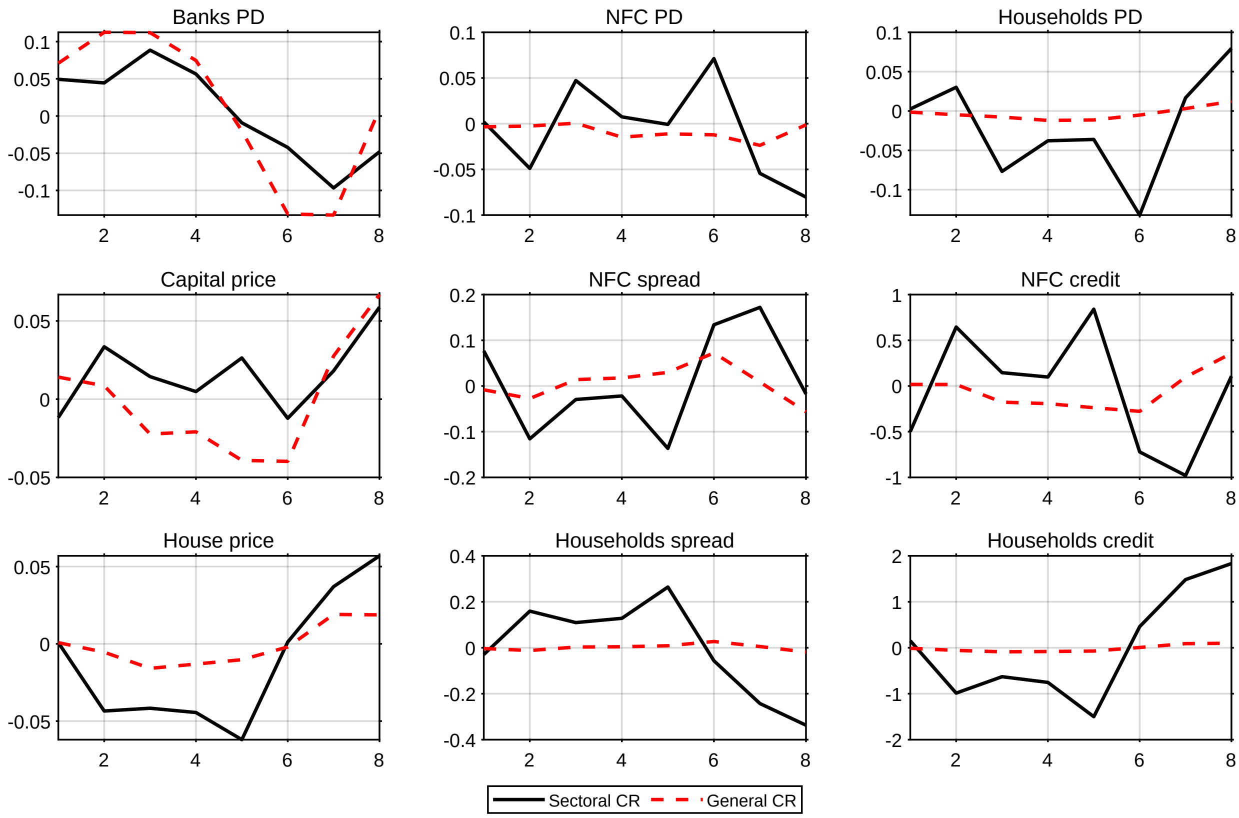
Notes. The black line presents the difference between the actual path minus the counterfactual path. Colours presents the contribution of each shock to this overall impact. The x-axis represents quarters, the first one being Q3 2021. All variables are in deviation from steady state in percent, except interest rates spreads, which are in percentage point.

Figure 9: Impact of Basel III from 2021-Q2 to 2023-Q2 - Distributive effects



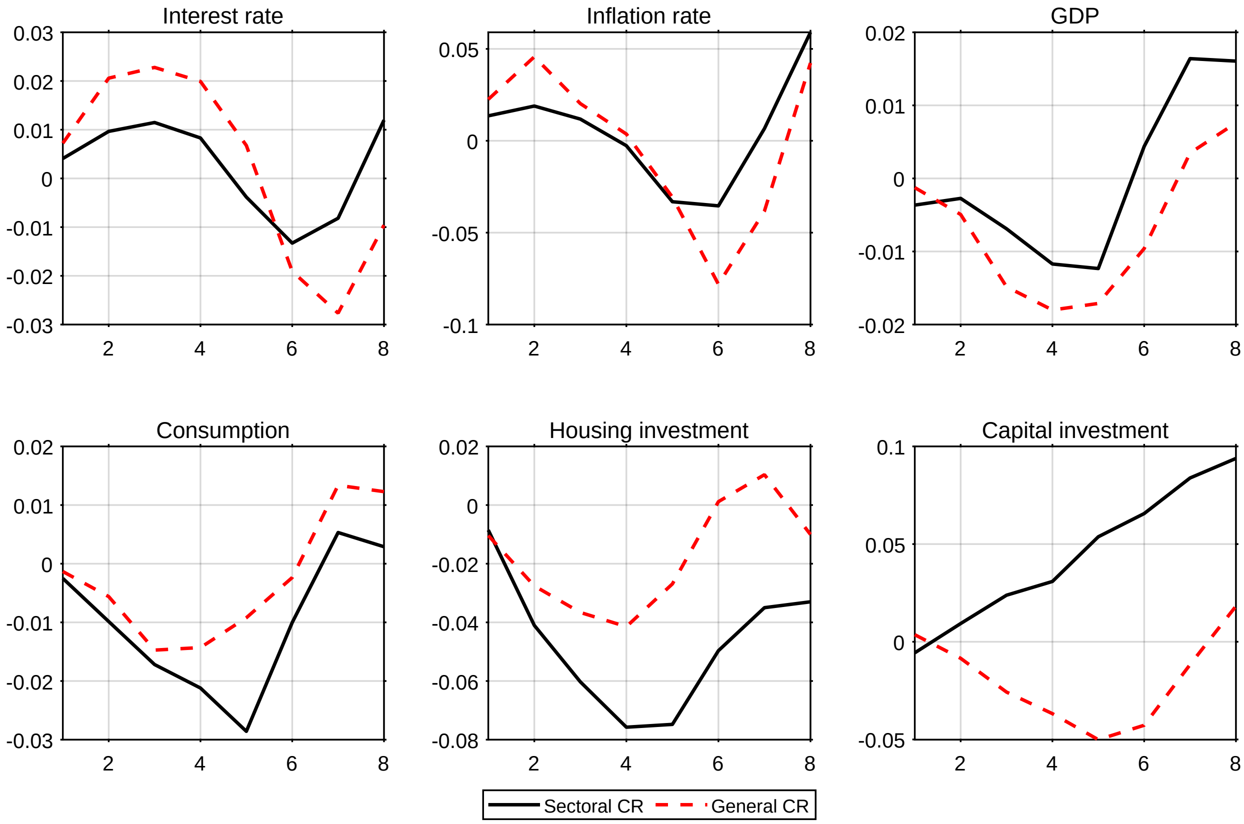
Notes. The black line presents the difference between the actual path minus the counterfactual path. Colours presents the contribution of each shock to this overall impact. The x-axis represents quarters, the first one being Q3 2021. All variables are in deviation from steady state in percent.

Figure 10: Impact of macroprudential policies - Financial variables



Notes. All lines present the difference between the actual path minus the counterfactual path. The x-axis represents quarters, the first one being Q3 2021. All variables are in deviation from steady state in percent, except the interest rate and the inflation rate, which are in percentage point.

Figure 11: Impact of macroprudential policies - Macroeconomic variables



Notes. All lines present the difference between the actual path minus the counterfactual path. The x-axis represents quarters, the first one being Q3 2021. All variables are in deviation from steady state in percent, except spreads and probabilities of default, which are in percentage point.

B Equilibrium conditions

To simplify the exposition, we redefine a number of variables

$$\begin{aligned} b_t^e &\leftarrow m^e b_t^e, \\ k_t^e &\leftarrow m^e k_t^e, \\ n_t^e &\leftarrow m^e n_t^e, \\ n_t^b &\leftarrow m^b n_t^b. \end{aligned}$$

We let Φ denote the CDF of the $\mathcal{N}(0,1)$ distribution. The threshold value of idiosyncratic shock above which an entity default is denoted $\bar{\omega}_t^j$, where $j \in \{e,i,F,M\}$.

We also express capital requirements as a leverage ratio combining the broad base capital requirement as well as sector-specific risk weights:

$$f_t^F = \phi_t \gamma_t^F$$

$$f_t^M = \phi_t \gamma_t^M$$

Intermediary and final good producer:

$$w_t = s_t \mathrm{e}^{\zeta_{a,t}} (1-\alpha) \mathrm{e}^{\zeta_{z,t}} \left(\frac{k_{t-1}}{\mathrm{e}^{\zeta_{z,t}} \ell_t} \right)^{\alpha} \tag{B.1}$$

$$r_t^K = s_t \mathrm{e}^{\zeta_{a,t}} \alpha \left(\frac{k_{t-1}}{\mathrm{e}^{\zeta_{z,t}} \ell_t} \right)^{\alpha-1} \tag{B.2}$$

$$\bar{P}_t^{\star} = \frac{K_{1,t}}{K_{2,t}} \tag{B.3}$$

$$K_{1,t} = \mu_t y_t s_t + (\beta^p \xi) \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} \left(\frac{(\Pi_*)^{1-\iota} (\Pi_t)^{\iota}}{\Pi_{t+1}} \right)^{\frac{\mu_t}{1-\mu_t}} K_{1,t+1} \right] \tag{B.4}$$

$$K_{2,t} = y_t + (\beta^p \xi) \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} \left(\frac{(\Pi_*)^{1-\iota} (\Pi_t)^{\iota}}{\Pi_{t+1}} \right)^{\frac{1}{1-\mu_t}} K_{2,t+1} \right] \tag{B.5}$$

$$1 = (1-\xi)(\bar{P}_t^{\star})^{\frac{1}{1-\mu_t}} + \xi \left[\frac{(\Pi_*)^{1-\iota} (\Pi_{t-1})^{\iota}}{\Pi_t} \right]^{\frac{1}{1-\mu_t}} \tag{B.6}$$

$$\Upsilon_t^{\frac{\mu_t}{1-\mu_t}} y_t = \mathrm{e}^{\zeta_{a,t}} (k_{t-1})^{\alpha} (\mathrm{e}^{\zeta_{z,t}} \ell_t)^{1-\alpha} \tag{B.7}$$

$$\Upsilon_t^{\frac{\mu_t}{1-\mu_t}} = (1-\xi)(\bar{P}_t^{\star})^{\frac{\mu_t}{1-\mu_t}} + \xi \left(\frac{(\Pi_*)^{1-\iota}(\Pi_{t-1})^{\iota}}{\Pi_t} \right)^{\frac{\mu_t}{1-\mu_t}} \Upsilon_{t-1}^{\frac{\mu_t}{1-\mu_t}} \tag{B.8}$$

Capital production:

$$q_t^K = \mathrm{e}^{\zeta_{i_K,t}} \left(1 + \frac{\psi_K}{2} \left(\frac{i_t^K}{i_{t-1}^K} - 1 \right)^2 + \psi_K \left(\frac{i_t^K}{i_{t-1}^K} - 1 \right) \frac{i_t^K}{i_{t-1}^K} \right) - \beta^p \mathbb{E}_t \left[\mathrm{e}^{\zeta_{i_K,t+1}} \frac{\lambda_{t+1}^p}{\lambda_t^p} \psi_K \left(\frac{i_{t+1}^K}{i_t^K} - 1 \right) \left(\frac{i_{t+1}^K}{i_t^K} \right)^2 \right] \tag{B.9}$$

$$k_t = (1-\delta^K) k_{t-1} + i_t^K \tag{B.10}$$

Housing production:

$$q_t^H = \mathrm{e}^{\zeta_{i_H,t}} \left(1 + \frac{\psi_H}{2} \left(\frac{i_t^H}{i_{t-1}^H} - 1 \right)^2 + \psi_H \left(\frac{i_t^H}{i_{t-1}^H} - 1 \right) \frac{i_t^H}{i_{t-1}^H} \right) - \beta^p \mathbb{E}_t \left[\mathrm{e}^{\zeta_{i_H,t+1}} \frac{\lambda_{t+1}^p}{\lambda_t^p} \psi_H \left(\frac{i_{t+1}^H}{i_t^H} - 1 \right) \left(\frac{i_{t+1}^H}{i_t^H} \right)^2 \right] \tag{B.11}$$

$$h_t = (1-\delta^H) h_{t-1} + i_t^H \tag{B.12}$$

Patient Households:

$$\lambda_t^p = \frac{\mathrm{e}^{\zeta_{c,t}}}{c_t^p - \psi c_{t-1}^p} \tag{B.13}$$

$$\mathrm{e}^{\zeta_{c,t}} \varphi^p J_t^p (\ell_t^p)^{\eta} = w_t \tag{B.14}$$

$$J_t^p = (J_{t-1}^p)^{1-\zeta_J} [(c_t^p - \psi c_{t-1}^p)]^{\zeta_J} \tag{B.15}$$

$$\lambda_t^p = \beta^p \mathbb{E}_t \left[\lambda_{t+1}^p \frac{\tilde{R}_{t+1}}{\Pi_{t+1}} \right] \tag{B.16}$$

$$\lambda_t^p (q_t^K + \xi_s m^p k_t^p) = \beta^p \mathbb{E}_t \left[\lambda_{t+1}^p [r_{t+1}^K + (1-\delta^K) q_{t+1}^K] \right] \tag{B.17}$$

$$\lambda_t^p q_t^H = \mathrm{e}^{\zeta_{c,t}} \upsilon^p \frac{1}{h_t^p} + \beta^p (1-\delta^H) \lambda_{t+1}^p q_{t+1}^H \tag{B.18}$$

Bankers and banks:

$$v_t^b = \beta^p \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} (1-\theta^b + \theta^b v_{t+1}^b) \frac{Z_{t+1}^M}{\Pi_{t+1}} \right] \tag{B.19}$$

$$v_t^b = \beta^p \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} (1-\theta^b + \theta^b v_{t+1}^b) \frac{Z_{t+1}^F}{\Pi_{t+1}} \right] \tag{B.20}$$

$$\bar{\omega}_t^M = (1 - f_{t-1}^M) \frac{R_{t-1}}{R_t^M} \tag{B.21}$$

$$\bar{\omega}_t^F = (1 - f_{t-1}^F) \frac{R_{t-1}}{R_t^F} \tag{B.22}$$

$$Z_t^M = \frac{(1-\Gamma_t^M) R_t^M}{f_{t-1}^M} \tag{B.23}$$

$$Z_t^F = \frac{(1-\Gamma_t^F) R_t^F}{f_{t-1}^F} \tag{B.24}$$

$$n_t^b = [\theta^b + \chi^b (1-\theta^b)] \left(\frac{Z_t^M}{\Pi_t} f_{t-1}^M m^i b_{t-1}^i + \frac{Z_t^F}{\Pi_t} f_{t-1}^F b_{t-1}^e \right) \tag{B.25}$$

$$n_t^b = f_t^M m^i b_t^i + f_t^F b_t^e \tag{B.26}$$

Entrepreneurs and investment firms:

$$v_t^e = \mathbb{E}_t \left[\beta^p \frac{\lambda_{t+1}^p}{\lambda_t^p} (1-\theta^e + \theta^e v_{t+1}^e) \frac{Z_{t+1}^e}{\Pi_{t+1}} \right] \tag{B.27}$$

$$x_t^e = \frac{R_t^e b_t^e}{q_t^K k_t^e} \tag{B.28}$$

$$\bar{\omega}_t^e = \frac{x_{t-1}^e}{R_t^K} \tag{B.29}$$

$$R_t^K = \Pi_t \frac{r_t^K + (1-\delta) q_t^K}{q_{t-1}^K} \tag{B.30}$$

$$R^F_t = (\Gamma^e_t - \mu^e G^e_t) R^K_t \frac{q^K_{t-1} k^e_{t-1}}{b^e_{t-1}} \tag{B.31}$$

$$Z^e_t = (1-\Gamma^e_t) R^K_t \frac{q^K_{t-1} k^e_{t-1}}{n^e_{t-1}} \tag{B.32}$$

$$\mathbb{E}_t \Bigg[\beta^p \frac{\lambda^p_{t+1}}{\lambda^p_t} \frac{1}{\Pi_{t+1}} \Big((1-\theta^e + \theta^e v^e_{t+1}) \Gamma^{e\prime}_{t+1} - \xi^e_t (1-\theta^b + \theta^b v^b_{t+1})(1-\Gamma^F_{t+1})(\Gamma^{e\prime}_{t+1} - \mu^e G^{e\prime}_{t+1}) \Big) \Bigg] = 0 \tag{B.33}$$

$$\mathbb{E}_t \Bigg[\beta^p \frac{\lambda^p_{t+1}}{\lambda^p_t} \Big((1-\theta^e + \theta^e v^e_{t+1})(1-\Gamma^e_{t+1}) + \xi^e_t (1-\theta^b + \theta^b v^b_{t+1})(1-\Gamma^F_{t+1})(\Gamma^e_{t+1} - \mu^e G^e_{t+1}) \Big) \frac{R^K_{t+1}}{\Pi_{t+1}} \Bigg] - \xi^e_t f^F_t v^b_t = 0 \tag{B.34}$$

$$n^e_t = [\theta^e + \chi^e(1-\theta^e)](1-\Gamma^e_t)(r^K_t + (1-\delta) q^K_t) k^e_{t-1}, \tag{B.35}$$

$$n^e_t + b^e_t = q^K_t k^e_t \tag{B.36}$$

Impatient households:

$$R^M_t = (\Gamma^i_t - \mu^i G^i_t) \frac{R^H_t q^H_{t-1} h^i_{t-1}}{b^i_{t-1}} \tag{B.37}$$

$$c^i_t + q^H_t h^i_t = w_t \ell^i_t + b^i_t + (1-\Gamma^i_t)(1-\delta^H) q^H_t h^i_{t-1} \tag{B.38}$$

$$R^H_t = \Pi_t \frac{(1-\delta^H) q^H_t}{q^H_{t-1}} \tag{B.39}$$

$$x^i_t = \frac{R^i_t b^i_t}{q^H_t h^i_t} \tag{B.40}$$

$$\bar{\omega}^i_t = \frac{x^i_{t-1}}{R^H_t} \tag{B.41}$$

$$\lambda_t^i = \frac{e^{\zeta_{c,t}}}{c_t^i - \psi c_{t-1}^i} \tag{B.42}$$

$$w_t = e^{\zeta_{c,t}} \varphi^i J_t^i (\ell_t^i)^\eta \tag{B.43}$$

$$J_t^i = (J_{t-1}^i)^{1-\zeta_J} [(c_t^i - \psi c_{t-1}^i)]^{\zeta_J} \tag{B.44}$$

$$\beta^i \mathbb{E}_t \left[\lambda_{t+1}^i \frac{\Gamma_{t+1}^{i\prime}}{\Pi_{t+1}} \right] = \xi_t^i \beta^p \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} (1 - \theta^b + \theta^b v_{t+s+1}^b)(1 - \Gamma_{t+1}^M) \frac{\Gamma_{t+1}^{i\prime} - \mu^i G_{t+1}^{i\prime}}{\Pi_{t+1}} \right] \tag{B.45}$$

$$\lambda_t^i = \xi_t^i f_t^M v_t^b \tag{B.46}$$

$$\lambda_t^i q_t^H = e^{\zeta_{c,t}} \upsilon^i \frac{1}{h_t^i} + \beta^i \mathbb{E}_t \left[\lambda_{t+1}^i (1 - \Gamma_{t+1}^i)(1 - \delta^H) q_{t+1}^H \right]$$
$$+ \beta^p \xi_t^i \mathbb{E}_t \left[\frac{\lambda_{t+1}^p}{\lambda_t^p} (1 - \theta^b + \theta^b v_{t+s+1}^b)(1 - \Gamma_{t+1}^M)(\Gamma_{t+1}^i - \mu^i G_{t+1}^i)(1 - \delta^H) q_{t+1}^H \right] \tag{B.47}$$

Market clearing:

$$k_t = k_t^e + m^p k_t^p \tag{B.48}$$

$$h_t = m^p h_t^p + m^i h_t^i \tag{B.49}$$

$$c_t = m^p c_t^p + m^i c_t^i \tag{B.50}$$

$$\ell_t = m^p \ell_t^p + m^i \ell_t^i \tag{B.51}$$

$$y_t = c_t + e^{\zeta_{i_K,t}} \left(1 + \frac{\psi_K}{2} \left(\frac{i_t^K}{i_{t-1}^K} - 1 \right)^2 \right) i_t^K + e^{\zeta_{i_H,t}} \left(1 + \frac{\psi_H}{2} \left(\frac{i_t^H}{i_{t-1}^H} - 1 \right)^2 \right) i_t^H + s_g y_* e^{\zeta_{g,t}}$$
$$+ \mu^i G_t^i (1 - \delta^H) q_t^H m^i h_{t-1}^i + \mu^e G_t^e (r_t^K + (1 - \delta) q_t^K) k_{t-1}^e$$
$$+ \mu^M G_t^M \frac{R_t^M}{\Pi_t} m^i b_{t-1}^i + \mu^F G_t^F \frac{R_t^F}{\Pi_t} b_{t-1}^e + \frac{\xi_s}{2} (m^p k_t^p)^2 \tag{B.52}$$

Deposit insurance:

$$\tilde{R}_t = R_{t-1} - (1-\kappa)\Omega_t \tag{B.53}$$

$$\Omega_t d_{t-1} = (\bar{\omega}_t^M - \Gamma_t^M + \mu^M G_t^M) R_t^M m^i b_{t-1}^i + (\bar{\omega}_t^F - \Gamma_t^F + \mu^F G_t^F) R_t^F b_{t-1}^e \tag{B.54}$$

$$n_t^b + d_t = b_t^e + m^i b_t^i \tag{B.55}$$

Monetary authority:

$$\log\left(\frac{R_t}{R_*}\right) = \rho_R \log\left(\frac{R_{t-1}}{R_*}\right) + (1-\rho_R)\left[a_\Pi \log\left(\frac{\Pi_t}{\Pi_*}\right) + a_y \log\left(\frac{GDP_t}{GDP_{t-1}}\right)\right] + \zeta_{R,t} \tag{B.56}$$

Exogenous processes:

$$\zeta_{a,t} = \rho_a \zeta_{a,t-1} + \frac{\sigma_a}{100}\varepsilon_{a,t}, \tag{B.57}$$

$$\zeta_{z,t} = \rho_z \zeta_{z,t-1} + \frac{\sigma_z}{100}\varepsilon_{z,t}, \tag{B.58}$$

$$\zeta_{i_K,t} = \rho_{i_K} \zeta_{i_K,t-1} + \frac{\sigma_{i_K}}{100}\varepsilon_{i_K,t}, \tag{B.59}$$

$$\zeta_{i_H,t} = \rho_{i_H} \zeta_{i_H,t-1} + \frac{\sigma_{i_H}}{100}\varepsilon_{i_H,t}, \tag{B.60}$$

$$\zeta_{e,t} = \rho_e \zeta_{e,t-1} + \frac{\sigma_e}{100}\varepsilon_{e,t}, \tag{B.61}$$

$$\zeta_{i,t} = \rho_i \zeta_{i,t-1} + \frac{\sigma_i}{100}\varepsilon_{i,t}, \tag{B.62}$$

$$\zeta_{B,t} = \rho_B \zeta_{B,t-1} + \frac{\sigma_B}{100}\varepsilon_{B,t}, \tag{B.63}$$

$$\zeta_{c,t} = \rho_c \zeta_{c,t-1} + \frac{\sigma_c}{100}\varepsilon_{c,t}, \tag{B.64}$$

$$\zeta_{\mu,t} = \rho_\mu \zeta_{\mu,t-1} + \frac{\sigma_\mu}{100}\varepsilon_{\mu,t}, \tag{B.65}$$

$$\zeta_{g,t} = \rho_g \zeta_{g,t-1} + \frac{\sigma_g}{100}\varepsilon_{g,t}, \tag{B.66}$$

$$\zeta_{R,t} = \frac{\sigma_R}{100}\varepsilon_{R,t}, \tag{B.67}$$

Auxiliary variables:

$$\Gamma_t^F = G_t^F + \bar{\omega}_t^F \left[1 - \Phi\left(\frac{\log(\bar{\omega}_t^F) + \frac{1}{2}(\sigma_F e^{\zeta_{B,t}})^2}{\sigma_F e^{\zeta_{B,t}}}\right)\right] \tag{B.68}$$

$$G_t^F = \Phi\left(\frac{\log(\bar{\omega}_t^F) - \frac{1}{2}(\sigma_F e^{\zeta_{B,t}})^2}{\sigma_F e^{\zeta_{B,t}}}\right) \tag{B.69}$$

$$\Gamma_t^M = G_t^M + \bar{\omega}_t^M \left[1 - \Phi\left(\frac{\log(\bar{\omega}_t^M) + \frac{1}{2}(\sigma_M e^{\zeta_{B,t}})^2}{\sigma_M e^{\zeta_{B,t}}}\right)\right] \tag{B.70}$$

$$G_t^M = \Phi\left(\frac{\log(\bar{\omega}_t^M) - \frac{1}{2}(\sigma_M e^{\zeta_{B,t}})^2}{\sigma_M e^{\zeta_{B,t}}}\right) \tag{B.71}$$

$$\Gamma_t^e = G_t^e + \bar{\omega}_t^e \left[1 - \Phi\left(\frac{\log(\bar{\omega}_t^e) + \frac{1}{2}(\sigma_e e^{\zeta_{e,t}})^2}{\sigma_e e^{\zeta_{e,t}}}\right)\right] \tag{B.72}$$

$$G_t^e = \Phi\left(\frac{\log(\bar{\omega}_t^e) - \frac{1}{2}(\sigma_e e^{\zeta_{e,t}})^2}{\sigma_e e^{\zeta_{e,t}}}\right) \tag{B.73}$$

$$\Gamma_t^{e\prime} = 1 - \Phi\left(\frac{\log(\bar{\omega}_t^e) + \frac{1}{2}(\sigma_e e^{\zeta_{e,t}})^2}{\sigma_e e^{\zeta_{e,t}}}\right) \tag{B.74}$$

$$G_t^{e\prime} = \frac{1}{\sigma_e e^{\zeta_{e,t}}}\varphi\left(\frac{\log(\bar{\omega}_t^e) + \frac{1}{2}(\sigma_e e^{\zeta_{e,t}})^2}{\sigma_e e^{\zeta_{e,t}}}\right) \tag{B.75}$$

$$\Gamma_t^i = G_t^i + \bar{\omega}_t^i \left[1 - \Phi\left(\frac{\log(\bar{\omega}_t^i) + \frac{1}{2}(\sigma_i e^{\zeta_{i,t}})^2}{\sigma_i e^{\zeta_{i,t}}}\right)\right], \tag{B.76}$$

$$G_t^i = \Phi\left(\frac{\log(\bar{\omega}_t^i) - \frac{1}{2}(\sigma_i e^{\zeta_{i,t}})^2}{\sigma_i e^{\zeta_{i,t}}}\right) \tag{B.77}$$

$$\Gamma_t^{i\prime} = 1 - \Phi\left(\frac{\log(\bar{\omega}_t^i) + \frac{1}{2}(\sigma_i e^{\zeta_{i,t}})^2}{\sigma_i e^{\zeta_{i,t}}}\right) \tag{B.78}$$

$$G_t^{i\prime} = \frac{1}{\sigma_i e^{\zeta_{i,t}}}\varphi\left(\frac{\log(\bar{\omega}_t^i) + \frac{1}{2}(\sigma_i e^{\zeta_{i,t}})^2}{\sigma_i e^{\zeta_{i,t}}}\right) \tag{B.79}$$

$$S_t^b = \beta^p \frac{\lambda_t^p}{\lambda_{t-1}^p}(1-\theta^b+\theta^b v_t^b) \tag{B.80}$$

$$S_t^e = \beta^p \frac{\lambda_t^p}{\lambda_{t-1}^p}(1-\theta^e+\theta^e v_t^e). \tag{B.81}$$

$$\begin{aligned} GDP_t = m^i c_t^i + m^p c_t^p + \mathrm{e}^{\zeta_{i_K,t}}\left(1+\frac{\psi_K}{2}\left(\frac{i_t^K}{i_{t-1}^K}-1\right)^2\right) i_t^K \\ + \mathrm{e}^{\zeta_{i_H,t}}\left(1+\frac{\psi_H}{2}\left(\frac{i_t^H}{i_{t-1}^H}-1\right)^2\right) i_t^H + s_g y_* \mathrm{e}^{\zeta_{g,t}} \end{aligned} \tag{B.82}$$